[COMMITTEE PRINT]

SPACE ACTIVITIES OF THE UNITED STATES, SOVIET UNION, AND OTHER LAUNCHING COUNTRIES/ORGANIZATIONS: 1957–1981

REPORT

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FOR THE

SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS

TRANSMITTED TO THE

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*On assignment to Budget Committee for 97th Congress.

LETTER OF TRANSMITTAL

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS,
Washington, D.C., May 1982.

Hon. DON FUQUA,
Chairman, Committee on Science and Technology.

DEAR MR. CHAIRMAN:

I am forwarding herewith a Congressional Research Service report, "Space Activities of the United States, Soviet Union, and Other Launching Countries/Organizations." This report constitutes the most authoritative review of the Soviet space program in the open literature and serves as a significant reference document while providing a comparison to the United States' space program.

Sincerely,

RONNIE FLIPPO,
Chairman, Subcommittee on Space Science and Applications.

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LETTER OF SUBMITTAL

May 7, 1982

Honorable Ronnie Flippo
Chairman, Subcommittee on Space Science
and Applications
Committee on Science and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

Pursuant to your request, we are hereby transmitting to you an original copy of the CRS Report Space Activities of the United States, Soviet Union, and Other Launching Countries/Organizations: 1957-1981 for your use. The study is a revised and expanded update of the report United States and Soviet Progress in Space which was prepared on an annual basis by our late colleague Dr. Charles Sheldon II, Senior Specialist in Space and Transportation Technology. Ms. Marcia Smith, Specialist in Aerospace and Energy Systems of the Science Policy Research Division, has updated Dr. Sheldon's text and tables on the U.S. and Soviet space programs, and added a section on space activities of the other launching countries/organizations (China, the European Space Agency, India, and Japan). Mr. Geoffrey Perry, M.B.E., head of the Kettering Group in England, provided some of the data for the tables in the report.

We hope that this report will serve you and the members of your subcommittee in your continuing oversight of U.S. space activities. With best regards,

Sincerely,

Gilbert Gude
Director

Enclosures

SPACE ACTIVITIES OF THE UNITED STATES, SOVIET UNION AND OTHER LAUNCHING COUNTRIES/ORGANIZATIONS: 1957-1981

by

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Science Policy Research Division
Congressional Research Service

February 26, 1982

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ABSTRACT

The United States and Soviet Union have been involved in launching satellites for almost 25 years. Both programs are large and comprehensive, competing across a broad spectrum of military and civilian applications. While these two nations have been the primary focus of space activities for the past two decades, the 1980's will probably witness the emergence of several other governmental space programs. China, the European Space Agency (a group of eleven European countries), India, and Japan all have an existing capability to place satellites into orbit and will increase the competition both for commercial traffic and for international prestige. In addition, these entities may also begin to launch military satellites (probably for reconnaissance purposes), breaking the hold that the United States and Soviet Union have had in obtaining information in this area.

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INTRODUCTION

Since October 4, 1957 when Sputnik 1 was placed in orbit by the Soviet Union, the question of Soviet-American rivalry in space and its broader implications have been matters of public concern, waxing and waning with the irregular occurrence of new space spectaculars. Sometimes the questions raised by space events have been matters of serious economic and military concern; other times they have been domestic and international political issues.

During the 1970's, developmental work on space launch vehicles was performed by several other countries. By 1981, three individual countries (China, India, and Japan) and one international organization representing eleven Member States (the European Space Agency) had developed independent launch capabilities. The decade of the 1980's is likely to see the emergence of these entities as important factors in space utilization and competition.

The purpose of this report is to summarize the programs of the United States, Soviet Union, and the space programs of these other "launcher" countries. Not included are efforts by private groups in the United States and abroad (such as OTRAG and Space Services, Inc.) that are attempting to develop their own launch capabilities; if they succeed, these programs will be included in future editions of this report.

Part I of this report is an updated edition of "United States and Soviet Progress in Space: Summary Data Through 1980 and a Forward Look." Dr. Charles S. Sheldon II, who prepared that annual review of U.S. and Soviet space activities for more than a decade, died of cancer in September 1981. Part I still reflects a great deal of Dr. Sheldon's work, and was revised and updated

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by Marcia S. Smith, Specialist in Aerospace and Energy Systems in the Science Policy Research Division. Mr. Geoffrey Perry, M.B.E., head of the Kettering Group in England, provided some of the data for updating tables throughout Part I. Part II was prepared by Ms. Smith.

CRS has prepared several other reports on space which the reader may wish to consult for further information. A series of five-year studies on Soviet Space Programs has been prepared for the Senate Aeronautical and Space Sciences Committee (now part of the Senate Commerce, Science, and Transportation Committee) since the early 1960's. The most recent of these covers the years 1971-1975; parts of the next five-year update should be available during 1982. Worldwide Space Activities, which provides detailed information on the space activities of all countries in the world except the United States and Soviet Union, was prepared for the House Science and Technology Committee in 1977. United States Civilian Space Programs 1958-1978 (Volume I) was published by the same House committee in 1981. (Volume II, concerning applications satellites, should be available in 1982.)

Five CRS issue briefs are also available on space topics: Antisatellites (Killer Satellites), Issue Brief 81123; Earth Resources Satellite System--LANDSAT, Issue Brief 78007; Solar Energy from Space: Satellite Power Station, Issue Brief 78012; Space Policy and Funding: NASA and DOD, Issue Brief 78093; and Space Shuttle, Issue Brief 81175. These issue briefs are continuously updated as new information warrants.

This report, both introductory overviews and new information, is based on careful analysis of information contained in the numerous, unclassified, and the most recent of the sources cited in the above committee prints. Detailed citations are omitted for the purpose of keeping this annual update brief. The most frequently used sources, however, are publications of the Foreign Broadcast Information Service (FBIS), the Joint Publication Research Service, and the technical journal Aviation Week and Space Technology.

SUMMARY OF SIGNIFICANT 1981 SPACE ACTIVITIES

This was an important year in the history of the U.S. space program, with the successful launching of the space shuttle, a reusable space transportation system which is hoped to make access to space routine and relatively inexpensive. Two orbital flight tests of the shuttle were accomplished. In total, the United States made 18 successful launches during 1981 and had one launch failure. A previously launched space probe, Voyager 2, sent back photographs and data from Saturn, and began its journey to Uranus (it will reach that planet in 1986).

The Soviet Union placed a record number of payloads into orbit (148), but the 98 launches required to place these objects in space did not surpass the previous 1976 Soviet record of 99 launches. The Western trade press reported that the Soviets had two launch failures in 1981. The Soviets made three manned flights to the Salyut 6 space station, and announced that they would retire the Soyuz spacecraft, which had been in service since 1967, and rely on an improved, modified version of Soyuz designated Soyuz T. Comments from prominent personalities associated with the Soviet space program suggested that the Soviets would not launch a reusable space vehicle similar to the U.S. shuttle in the near future although they did not rule out the prospect that such a program is underway. An unmanned spacecraft, Kosmos 1267, was docked with the Salyut 6 space station in June and became the subject of concern when the Western trade press reported that it was armed with infrared homing vehicles and was a "battle station" in orbit. The Soviets claim that it is being used to test the concept

of a modular space station, in which a core station could be enlarged by docking additional modules to it. At the end of 1981, Kosmos 1267 remained docked with Salyut 6, its mission unclear. The Soviets also conducted two more tests of its antisatellite system in 1981. In the planetary program, the Soviets sent two spacecraft to Venus, with landings expected in March 1982.

Japan made three successful launches in 1981, including use of a new launch vehicle, called the N II. After a two year hiatus, the Peoples Republic of China resumed space launchings, and placed three satellites in orbit with one launch vehicle, an important step in the evolution of a space program. India succeeded in launching the Indian-built satellite Rohini 2 with its own launch vehicle, the SLV-3. Although the satellite did not reach the proper orbit, it was another step in India's development of an independent space program. India also continued its cooperation with the Soviet Union with the launch of the Indian Bhaskara earth resources satellite by the Soviets in November.

The European Space Agency successfully completed its tests of the new Ariane launch vehicle and announced that the system is now operational. Ariane can place two satellites into geostationary orbit at the same time (thereby reducing costs), and will directly compete for commercial traffic with the U.S. space shuttle. During 1981, three U.S. companies which had planned to use the shuttle for launching satellites switched to Ariane instead.

PART ONE

U.S. AND SOVIET SPACE ACTIVITIES

CHAPTER ONE: BRIEF HISTORY

A. WORLD WAR II

Building upon a foundation of scientific principles common to much of the world, the Germans developed to a high degree of engineering success the technology of long-range guided rockets, of which the V-2 was the most spectacular. At the end of the war, most of the leading German rocket scientists and engineers surrendered to the United States, while smaller numbers and the Peenemunde missile development center came under Soviet control. The German experience stimulated interest in rocketry, and their practical knowledge was quite useful, but it would be a mistake to judge the primary rocket programs of either the United States or the Soviet Union as depending exclusively upon this captured talent. The Russians in particular had a strong tactical rocket program in World War II, and as they moved into long-range ballistic missiles and space, they reportedly did not use Germans directly in their work on any significant scale.

B. THE INTERNATIONAL GEOPHYSICAL YEAR (IGY)

In 1955 both the United States and the Soviet Union announced their intentions to launch by 1957 small scientific satellites as a contribution to world understanding of Earth and space physics. The U.S. project was to be called Vanguard, with a payload of about 9 kilograms. Fewer details were available about Soviet plans.

C. SPUTNIK VS. VANGUARD AND EXPLORER

The general public, and many specialists who might have known better, were caught off guard when Sputnik 1 was placed in Earth orbit, with a weight of 84 kilograms. Few had supposed that the "backward" U.S.S.R. would beat the scientifically-advanced United States in this particular endeavor. One Western reaction was that this and subsequent Soviet achievements were fakes; and another reaction was one of near panic with thoughts of bombs dropped from orbit. Sputnik 2, launched November 3, 1957, did not help U.S. complacency when it was disclosed to weigh 508 kilograms, and to carry a live dog, Layka. U.S. discomfiture, at the very least, was heightened by the explosion on the pad of the widely-advertised first launch attempt of a 2-kilogram Vanguard on December 6, 1957. On May 15, 1958, Sputnik 3 went into orbit as a comprehensive orbital laboratory of 1,327 kilograms. Meanwhile the United States had outpaced its own Vanguard series (Navy-built for the National Academy of Sciences) with Explorer 1 (Army-built) of 8 kilograms payload on January 31, 1958 (Eastern Standard time). Vanguard 1 was launched March 17, 1958.

D. MOON FLIGHTS, LUNA 1-3 VS. PIONEER AND RANGER

In 1958, the United States began a double series of Pioneer flights--one to photograph the far side of the Moon and the other to fly by it. All four launch attempts in that year failed to reach the Moon. In January 1959, the Russians launched Luna 1 which sent 361 kilograms past the Moon (apparently a miss) to circle the Sun. The U.S. National Aeronautics and Space Administration (NASA) followed in March 1959 with its 6 kilogram Pioneer 4 which went

by the Moon and circled the Sun. U.S. plans then were to follow up with four more, larger Pioneer series lunar orbit flights during the course of 1959 and 1960, but all of these failed to reach even Earth orbits. In fact, NASA did not reach the Moon until an early Ranger fell on the far side of the Moon (Ranger 4 in 1962). In September 1959, the Soviet Luna 2 struck the Moon near its visible center, delivering metal plaques bearing the Soviet coat of arms. Luna 3 in October 1959 flew by the Moon and by automatic means tooks photographs of the far side, never seen before, which were returned to Earth by radio facsimile. Still later, the U.S. Ranger 7, 8, and 9 flights in 1964-1965 returned spectacular TV pictures of the Moon up to the moment of impact.

E. MANNED ORBITAL FLIGHT, VOSTOK VS. MERCURY

While Mercury was still in its testing stage in the United States, with the goal of placing a man in Earth orbit for a nominal three orbits in a 1,360 kilogram ship, the Soviet Union moved more rapidly in this field, too, by exploiting its then larger launch vehicles. Starting in May 1960, test flights of a 4,700 kilogram ship were conducted, with the first successful recovery of two dogs in August of that year. On April 12, 1961, Yuriy Gagarin was placed in orbit in Vostok 1 for a single circuit of the Earth, and in the following August, German Titov repeated the flight but for 17 orbits.

Alan Shepard on May 5, 1961 in a Mercury Redstone (Freedom 7) had flown for 15 minutes about 480 kilometers downrange from the Cape. "Gus" Grisson repeated this type of flight on July 21, 1961. But John Glenn was the first American to make it all the way to orbit with his three loops on February 20, 1962 in a Mercury Atlas (Friendship 7).

The Soviet Union flew the next two sets of Vostok flights in pairs in 1962 and 1963, with a near co-orbit in one case and a near pass in the other. Valentina Tereshkova, the only woman to go into space, in her 48 orbits (with Vostok 6) gained more orbital time than all six Mercury astronauts combined (34 orbits).

F. GEMINI VS. VOSKHOD

The Russians were able to achieve some more firsts with Voskhod 1 in October 1964 which carried the first three man crew, and Voskhod 2 in March 1965 which provided the first 10-minute "space walk" (EVA) by Leonov. But after that the balance swung fairly sharply to the United States which conducted ten successful Gemini flights without any Soviet manned flights in the same period (1965-1966). U.S. two-man Gemini ships of about 3,600 kilograms weight were able to maneuver to change orbit, to rendezvous, and to dock with Agena target vehicles on several occasions. Using the Agena as a pusher rocket, Gemini flew as high as 1,369 kilometers, a new record. The United States also gained about 12 hours of EVA experience.

G. APOLLO AND SOYUZ TRAGEDIES

Before NASA could make the first manned launch with Apollo, there was the disastrous Apollo fire of January 27, 1967 which took the lives of three astronauts. This was both a great shock to the Nation and set back the program almost two years.

The Soviet Union had its own tragedy on April 24, 1967 when it tried to recover its first manned flight of the new Soyuz series. The parachute lines in the final phase of recovery became twisted, and Vladimir Komarov became the first human being to be killed in return from a space flight. This set back the Soviet program almost two years also, and the shock of this accident was taken very hard by the Russians.

At the end of the Soyuz 11 mission, on June 29, 1971, as the three man crew went through the routines for return to Earth, they fired explosive bolts to separate their orbital work compartment and service module from the recoverable command module. Unfortunately, a valve linking the two habitable compartments remained open at separation, and the men quickly were asphyxiated. Their capsule landed automatically, but they were dead.

H. THE SUCCESSFUL APOLLO PROGRAM

After test flights in Earth orbit, NASA took the bold step on December 21, 1968 of launching Apollo 8 with Frank Borman, James Lovell, and William Anders on the first manned Saturn V for ten close orbits of the Moon . The Apollo 11 flight, launched July 16, 1969, permitted Neil Armstrong and "Buzz" Aldrin to become the first men to set foot on the lunar surface on July 20, while Mike Collins orbited overhead.

Apollo 13, launched April 11, 1970, provided the most harrowing Moon mission when an explosion in the service module disabled some systems and cut consumable supplies, so that the crew, committed to going on, circumnavigated the Moon, using the lunar landing module as a lifeboat for all but Earth reentry.

The final flight, Apollo 17, launched on December 7, 1972, was the sixth successful manned landing, and the third to use a roving manned vehicle on the surface.

I. SOYUZ FLIGHTS

Soyuz manned flights resumed in October 1968, and by January 1969 had been used to dock two ships together (Soyuz 4 and 5), permitting crew transfer through EVA. Soyuz 6, 7, and 8 by October 1969, made a group coorbital flight with seven men but no dockings. Soyuz 9 set what was then a duration record by staying in orbit 18 days with a two-man crew. Soyuz 12 was a manned diagnostic flight after the Soyuz 11 tragedy. Soyuz 13 of December 1973 was a manned astronomical observatory flight. Soyuz 16 of December 1974 was a trial run for the Apollo-Soyuz flight to follow. Soyuz 22 in September 1976 was a manned Earth resources flight using a multispectral camera system from the German Democratic Republic.

J. THE SOVIET CIRCUMLUNAR PROGRAM

It had been expected in the mid-1960's that the Russians would be the first to send men around the Moon, if not make a landing. Their program did not hold to such a timetable, but was able to send unmanned versions around the Moon for return to Earth. Spaceships named Zond 4 through 8 made flights to lunar distances, and returned either to the Soviet Union or the Indian Ocean where they were picked up. The Zonds resembled Soyuz spacecraft without the orbital work compartment, and they were launched by a more powerful (D)

rocket. The program was abandoned before men were carried, probably partly because of uncertainties in man-rating the launch vehicle, and partly because the continued successes of Apollo landings made the Soviet circumlunar flights seem less pioneering.

K. SALYUT SPACE STATIONS

The Salyut 1 space station of 18.6 tons was placed in orbit on April 19, 1971. It had about 100 cubic meters of interior space, compared with 6 in The Apollo command module, 9 in Soyuz, and 357 in the American Skylab (see below).

Soyuz 10 was launched with a crew of three, docked with Salyut, but for unstated reasons they were not able to enter the station, so returned to Earth in 2 days. Soyuz 11 was also docked, and its mission ran 24 days long, successfully conducting medical, Earth resources, and astronomical experiments. This was the crew that died during preparations to reenter the atmosphere.

Salyut 2 failed early in its mission, after launch on April 3, 1973. This was followed by Kosmos 557, launched May 11, 1973, intended to be a Salyut, which failed as it reached orbit.

Salyut 3 was launched July 3, 1974, and differed from Salyut 1 in being a military vehicle by strong implication. (Indicators: An all military crew, telemetry and frequencies akin to other military flights, and a low orbit to improve Earth picture resolutions.) It was visited by Soyuz 14 during a 16-day flight. Soyuz 15 also went up to the station but was not able to dock and returned to Earth after only two days. The station continued to function in automatic mode and returned a data capsule in September 1974.

Salyut 4, launched December 26, 1974, was another civilian mission, flying higher than the military type, using the usual manned-flight frequencies and open communications. Soyuz 17 made a 30-day flight, with the crew in the station. On April 5, 1975, a Soyuz was launched to carry a crew to Salyut 4, but a problem in the booster rocket required an automatic abort which brought the crew back to Earth (unharmed) about 20 minutes after launch. Soyuz 18 followed, and conducted a 63-day mission, then the Soviet duration record. Soyuz 20 in November 1975 was the first automated, unmanned "resupply" flight to a station (Salyut 4), a 91-day mission.

Salyut 5, another military station, was launched June 22, 1976. Soyuz 21 was launched on July 6, and conducted a 49-day mission with the crew occupying the station. On October 14, Soyuz 23 attempted a revisit to Salyut 5, but was not able to complete the rendezvous, and returned to Earth after two days. Subsequently, on February 7, 1977, Soyuz 24 was launched on an 18-day mission and the crew reoccupied the station.

Salyut 6, an improved civilian station, was launched on September 29, 1977. On October 9, Soyuz 25 carried a crew up to enter the station, but a hard docking was not achieved and the crew brought their Soyuz to Earth two days after launch. Another attempt was made on December 10, with Soyuz 26, and this time the crew was able to enter the station, for the first time using a new airlock at the opposite end of the station. This started a program which brought a full flowering of the Soviet space station program of the Salyut type. The Soyuz 26 crew set a world duration record of 96 days, for a time

sharing the station with the crew of Soyuz 27 with whom they traded ferry craft, and also received fresh supplies of consumables and instruments in an automated resupply craft called Progress 1. They also had a visit from the crew of Soyuz 28, which included the first Czech cosmonaut.

Soyuz 29 was launched on June 15 with a fresh crew for Salyut 6, and set even greater records. They stayed up 140 days, trading ferry craft with the crew of Soyuz 31. They had visits from Soyuz 30 with a Polish cosmonaut and Soyuz 31 with a German Democratic Republic cosmonaut. Resupply missions were run by Progress 2, 3 and 4. This brought to ten the total number of successful visits to Salyut 6, with docking ports at both ends put to use. Extra-vehicular activities (EVA) occurred twice, and many experiments were run involving both a multispectral camera for Earth resources work, and a 1.5 meter mirror cryogenically cooled infrared telescope for astronomical work. Many space manufacturing experiments were carried out.

Soyuz 32 carried to orbit on February 25, 1979, the third long-duration crew to occupy Salyut 6. They were to be visited by the crew of Soyuz 33 including a Bulgarian cosmonaut, but that mission was aborted, and eventually their ferry craft was replaced by Soyuz 34 sent up unmanned, later returning them to Earth after a record stay of 175 days. Also, during 1979, the station was replenished by Progress 5, 6, and 7. After their return to Earth, the year ended with a new class of ferry craft with enhanced capabilities, named Soyuz-T, docked to the station as part of an unmanned exercise. The Soyuz-T mission lasted over 100 days.

Before 1980 was over, Salyut 6 had entered its fourth year of service. During 1980, Progress 8 made an automated resupply flight to the unmanned station, followed by the manned Soyuz 35 with a crew that stayed up for 185 days, a new record. The long-duration team was visited by another crew including a Hungarian in Soyuz 36, and they traded Soyuz craft. The advanced-design ferry, Soyuz T-2, carried the next visiting Soviet crew up to the station. Also during the year, there were other automated resupply missions by Progress 9, 10, and 11. Soyuz 37 carried up a visiting crew including a Vietnamese, trading ferries again to return to Earth in Soyuz 36. Soyuz 38 carried up a visiting crew including a Cuban, and then on October 11, the long-duration crew, originally sent up in Soyuz 35, came home in Soyuz 37. In November, Soyuz T-3 carried a three-man crew to the station on a 13-day flight, the first crew of that size since the ill-fated flight of Soyuz 11 back in 1971.

Three more manned flights to Salyut 6 were accomplished during 1981. The Soyuz T-4 crew remained on-board for 75 days, and was visited by the crews of Soyuz 39 and Soyuz 40. These last two missions also completed the program of launching representatives of the Interkosmos countries, with Mongolian and Romanian cosmonauts respectively. By the end of 1981, the total Salyut 6 record included 29 successful dockings out of 31 attempts. The station was also resupplied by Progress 12 in 1981. The Soviets announced that Soyuz 40 was the last flight of the Soyuz spacecraft, which had been in service since 1967. They will now rely on the modified Soyuz T.

In June 1981, the satellite Kosmos 1267 was docked with Salyut 6 and remained docked at the end of 1981. The Soviets announced that its purpose was testing of the modular space station concept, and that Kosmos 1267 had life support systems on-board. Later, the Western press reported that Kosmos 1267 was in fact a "battle station" in orbit, armed with infrared homing devices. The actual nature of Kosmos 1267 remains unclear.

In 1982, the launch of Salyut 7 is expected and it may be an improved version of Salyut 6. There are rumors that it will be the first of a series of space stations with multiple docking ports allowing several modules to be docked simultaneously, although it is not certain that Salyut 7 will in fact be the first of this series. The launch of a Soviet/French crew is also expected in 1982.

L. SKYLAB MISSIONS

After the Apollo Moon flights ended, the United States used a spare Saturn V to place in orbit a modified S-IVB stage equipped as a space station. Called Skylab, it was launched on May 14, 1973. Three Saturn I B vehicles were used to send up modified Apollo ferry craft to dock with Skylab. These missions lasted 28, 59, and 84 days respectively. A wide range of experiments was conducted successfully, especially impressive since the crews had to make difficult repairs to the station which had been damaged during launch.

M. APOLLO-SOYUZ TEST PROJECT

As a contribution toward detente, and as a spur to the development of a universal, androgynous docking system, the United States and Soviet Union agreed to work cooperatively to develop and to conduct a joint flight in which an Apollo carrying a special docking module would rendezvous and dock with a modified Soyuz. The flights began on July 15, 1975. Soyuz 19 was sent up from Tyuratam with Leonov and Kubasov, while the Apollo was launched from the Kennedy Space Center with Stafford, Slayton, and Brand. The two crews paid exchange visits after docking and performed joint experiments. Soyuz 19 returned to Earth after 6 days, and Apollo after 10 days.

N. THE U.S. SPACE SHUTTLE

NASA made its principal development program for the 1970's the creation of a reusable shuttle spacecraft to act as a ferry from Earth to orbit and return. Over a period of time, various configurations had been studied. The favored design for a period was for two completely resuable piloted stages. The booster stage would have been roughly the size of a 747 or C-5A; and the orbital stage about the size of a DC-8 or 707. Both were to be rocket-powered, burning hydrogen and oxygen. After a vertical takeoff with the two craft attached in parallel, the booster would have flown back to the launch site to be readied for the next trip. The upper stage was to fly on to orbit, and later return for reuse. Both stages were to land horizontally like aircraft. Analysis showed that although these craft

represented an economical combination in the long run, they involved cost-peaking problems during development which made their fiscal and political practicability questionable.

The plan finally proposed in early January 1972 traded off some reusability for annual development cost totals which could be given consideration within the kind of budget ceilings with which NASA has worked in recent years. This compromise offered fewer cost savings in flight operations, but was believed by NASA to represent the only approach which was feasible under existing fiscal conditions. It was hoped by the sponsors that the booster stage could be replaced later by a fully reusable design. What has been built is a reusable orbital stage about the size of a DC-9, powered by three hydrogen-oxygen engines from fuel contained in large external disposable and non-recoverable fuel tank. Two strap-on solid-fuel rockets are also used, which are jettisoned into the ocean and recovered for refurbishment and reuse. The shuttle can carry payloads measuring up to 4.6 meters in diameter by 18.3 meters long, and weighing up to 29,480 kilograms. It can accommodate a crew of two, plus up to five additional passengers, with a flight environment which would not require the special training and stresses of previous astronaut flight. Initially, the shuttle can remain in orbit for seven days although this may be lengthened to 30 days if additional power supplies are available. Its tasks will include ferrying people and supplies, supporting an attached Spacelab, launching other satellites, and potentially even acting as a rescue ship. The shuttle may be used to service other spacecraft in orbit, perhaps bringing them back to Earth for major overhaul if required.

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O. SUMMARY TABLE OF SPACE FLIGHTS

The table which follows gives annual totals for space launchings, payloads in Earth orbit, and payloads sent to the Moon or planets. The figures on successes are reasonably reliable because of requirements for registration at the United Nations, although there are some differences of interpretation in counts on pick-a-back payloads and whether orbiting platforms from which further launches are made should be counted as payloads.

The data on space failures are much more problematical. The United States publishes a launch failure count but not a count of payload losses. The Soviet Union (and presumably China) do not publish failure records. Hence, the table has to assume that the total Soviet failure count is in the same proportion to successes as applies in the United States; further, there is a reasonably safe inferential count of Soviet deep space payloads which became stranded in Earth orbit, whose total even exceeds the expected proportionate share comparable to U.S. experience.

Further details of interpretation of the contents of this table are contained in more comprehensive congressional documents such as the Senate Aeronautical and Space Sciences committee print reviewing the Soviet space program through 1975. Further details of the Chinese, Japanese, Indian and European space programs can be found in Part II of this report.

TABLE 1a — Worldwide Record of Known Space Launchings*

Year	SUCCESSES																		
	Launches							Payloads to Earth Orbit								Moon, Beyond	
	USSR	US	Japan	China	Italy	ESA**	India	USSR	US	Japan	China	Italy	ESA**	India	US	USSR
1957	2							2								
1958	1	5						1	5							
1959	3	10						9							1	3
1960	3	16						3	16						1	
1961	6	29						7	35							1
1962	20	52						25	55						4	1
1963	17	38						19	62							1
1964	30	57						37	69						4	2
1965	48	63						69	93						4	7
1966	44	73						47	94						7	5
1967	66	57			1			74	78			1			10	1
1968	74	45						81	61						3	4
1969	70	40						76	58						8#	4
1970	81	29	1	1	##			98	36	1	1	#			3	5
1971	83	31	2	1	1##			107	45	2	1	1#			8	7
1972	74	31	1		##			106	33	1		#			8	3
1973	86	23						123	23						3	7
1974	81	22	1		2			111	27	1		2			1	3
1975	89	28	2	3	##			136	30	2	3	#			4	4
1976	99	26	1	2				139	33	1	2				1	2
1977	98	24	2					125	27	2					2	
1978	88	32	3	1				138	34	3	1				7	4
1979	87	16	2			1		126	18	2			1			
1980	89	13	2				1	132	16	2				1		
1981	98	18	3	1		2	1	146	20	3	3		5	1		2
Total	1437	778	20	9	4	3	2	1928	977	20	11	4	6	2	79	66

* This table reflects those countries/organizations which currently have a space launching capability. It should be noted, however, that three other countries have successfully orbited payloads in the past. Britain made one successful space launch of a single payload in 1971 and had one failure in 1970. France had its own launch vehicle (Diamant) from 1965 through 1975, during which 10 successful launches of twelve payloads were made; there were two launch failures (three payloads). Australia made one launch of one payload in 1967.

** ESA refers to the European Space Agency.

\# Additionally, the United States sent one piece of debris to escape as part of an Earth orbital mission.

\## Italy launched in each of four years marked with this symbol a payload for the United States which are also included in the U.S. count, making a total of eight Italian launches and a net of 774 U.S. launches. The table makes no attempt to show separately other international cooperative payloads launched by the United States, the USSR, France, and Italy for 18 countries or international organizations; those launches and payloads are included in the data above.

TABLE 1b -- World Record of Known Space Launchings
FAILURES

Year	Launches							Payloads to Earth Orbit							Moon, Beyond	
	USSR	US	Japan	China	ELDO*	ESA**	India	USSR	US	Japan	China	ELDO*	ESA**	India	USSR	US
1957		1							1							
1958		12							8							4
1959		10							9							2
1960	2+?	13						2+?	12						2+?	2
1961		12							12						1+?	2
1962		7							12						5+?	1
1963		8							11						2+?	
1964		7							8						1+?	
1965		7							7						2+?	1
1966		4	2						12	2					1+?	1
1967		3	1						4	1					3+?	
1968		3			1				15			1				
1969		1	1	1	1				1	1		1			2+?	1
1970		1	1		1				1	1		1			1+?	
1971		3			1				2			1			1+?	1
1972		2							2						1+?	
1973		2							2							
1974		1							2							
1975	2+?	3						2+?	4							
1976			1							1						
1977		2							2							
1978		1							2							
1979				1+?			1				1+?			1		
1980		2				1			4				3			
1981	2?#	1						2?#	1							
Total	187?	106	6	2+?	4	1	1	25#?	134	6	1+?	4	3	1	22+?	15

* ELDO refers to the European Launch Development Organization.

** ESA refers to the European Space Agency.

Two U.S. escape distance failures were Earth orbital successes; 20 Soviet escape distance failures were Earth orbital successes. Only the USSR and China do not report launch failures; therefore failures for these two countries have been estimated by applying the U.S. failure rate to their launch successes totals; the only other Soviet and Chinese failures specifically noted are those which can be identified from official public sources. Failures of international cooperative payloads are included in the national totals shown above, and not listed separately by country or organization.

\# Defense Daily reported that there were two Soviet failures in 1981 (January 8, 1982).

CHAPTER TWO: TABLE OF SPACE "FIRSTS" -- U.S. AND SOVIET

Any attempt in simple form to compare the relative pace of the two principal space programs through a table of firsts has certain weaknesses, as it does not answer by how many days or years a particular event occurred in one country before another. Further, it does not distinguish between a nominal first accomplishment in crude form by one country, sometimes followed by a much more impressive and elaborate follow-up by the other country. Nonetheless, such firsts do affect public opinion, and analysis by various fields of endeavor may give some sense of relative direction of pacing efforts in each country. The table which follows attempts such a measure:

TABLE 2

Major Space "Firsts"

United States			Union of Soviet Socialist Republics		
Event	Satellite	Launch Date	Event	Satellite	Launch Date
Science			**Science**		
Van Allen radiation belts	Explorer 1	02/01/58	Orbiting geophysical lab	Sputnik 3	05/15/58
Earth shape measured	Vanguard 1	03/17/58	Farside lunar picture	Luna 3	10/04/59
Orbiting solar observatory	OSO 1	03/07/62	Cosmic ray measurements	Proton 1	07/16/65
Data from Venus	Mariner 2	08/27/62	Lunar surface pictures	Luna 9	01/31/66
Geodetic satellite	Anna 1B	10/31/62	Lunar surface bearing test	Luna 13	12/21/66
Lunar close-up pictures	Ranger 7	07/28/64	Venus atmospheric probe	Venera 4	06/12/67
Mars pictures	Mariner 4	11/28/64	Automated return of lunar sample	Luna 16	09/12/70
Micrometeorite satellite	Pegasus 1	02/16/65	Automated lunar roving laboratory	Luna 17	11/10/70
Lunar orbit pictures	Orbiter 1	08/10/66	Venus soil analysis	Venera 8	03/27/72
Lunar trenching	Surveyor 3	04/17/67	Venus surface pictures	Venera 9	06/08/75
Color picture of full Earth face	DODGE	07/01/67	Radio telescope 10-meter dish	Salyut 6	09/29/77
Lunar soil chemical analysis	Surveyor 5	09/08/67			
Point-stabilized Orbiting Astro-Observatory	OAO 2	12/07/68			
Live lunar TV broadcast	Apollo 8	12/21/68			
Return of lunar rocks	Apollo 11	07/16/69			
Long life lunar surface sensors	Apollo 12	11/14/69			
Color pictures of Jupiter	Pioneer 10	03/03/72			
Color pictures of Saturn	Pioneer 11	04/06/73			
Radiotelescope, far side Moon	Explorer 49	06/10/73			
Pictures of Venus	Mariner 10	11/03/73			
Pictures of Mercury	Mariner 10	11/03/73			
Solar Probe	Helios 1	12/10/74			
Mars surface pictures	Viking 1	08/22/75			
High energy astro observatory	HEAO 1	08/12/77			
Detailed Jupiter Moons surveys	Voyager 1	09/05/77			
Detailed Saturn Moons surveys	Voyager 1	09/05/77			

TABLE 2 (continued)

Applications		
Active communications	Score	12/18/58
TV pictures from space	Explorer 6	08/07/59
Weather satellite	Tiros 1	04/01/60
Navigation satellite	Transit 1B	04/13/60
Missile detection	Midas 2	05/24/60
Observation recoverable flight	Discoverer 13	08/10/60
Passive communications	Echo 1	08/12/60
Nuclear explosion detection	Vela Hotel	10/17/63
Earth resources satellite	ERTS 1	07/23/72
Synchronous 24-hour weather	SMS 1	05/17/74
Commercial maritime communications	Marisat 1	02/19/76
Sea resources satellite	SeaSat 1	06/27/78

Applications		
Domestic communications	Molniya 1-1	04/23/65
Fractional orbit bombardment	Kosmos 139	10/20/68
Satellite inspector/destructor	Kosmos 402?	04/01/71
Radar ocean surveillance	Kosmos 402?	04/01/71

Bio and Manned Flight		
Manned orbital maneuver	Gemini 3	03/23/65
Controlled extravehicular activity	Gemini 4	06/03/65
Manned space rendezvous	Gemini 6, 7	12/04/65
Manned docking	Gemini 8-Agena	03/16/66
Manned lunar orbit	Apollo 8	12/21/68
Manned lunar return reentry	Apollo 8	12/21/68
Lunar orbit rendezvous	Apollo 10	05/18/69
Lunar landing and return	Apollo 11	07/16/69
Lunar pinpoint landing	Apollo 12	11/14/69
Manned lunar rover	Apollo 15	07/26/71
28-day flight	Skylab 2	05/25/73
59.3-day flight	Skylab 3	07/28/73
84-day flight	Skylab 4	11/16/73
International docking	Apollo	07/15/75
Flight of reusable vehicle	STS 1	04/12/81

Bio and Manned Flight		
Biosatellite	Sputnik 2	11/03/57
Recovery, orbited animals	Korab 1 Sputnik 2	08/19/60
Recovery orbited man	Vostok 1	04/12/61
Multi-manned spacecraft	Voskhod 1	10/12/64
Extravehicular activity	Voskhod 2	03/18/65
Recovery, circumlunar live animals	Zond 5	09/21/68
Transfer crew between ships	Soyuz 4-5	1/14-15/59
18-day flight	Soyuz 9	06/01/70
Space station	Salyut 1	04/19/71
23.75-day flight	Soyuz 11	06/06/71
International docking	Soyuz 19	07/15/75
2 ferry craft docked to station	Soyuz 26-27	01/10/78
96-day flight	Soyuz 26-27	12/10/78
International crew launch	Soyuz 28	03/02/78
140-day flight	Soyuz 29-31	06/15/78
175-day flight	Soyuz 32-34	02/25/79
185-day flight	Soyuz 35-37	04/09/80

TABLE 2 (continued)

Space Flight and Propulsion			Space Flight and Propulsion		
Multiple spacecraft payload	Transit/ Solrad	06/22/60	Space flight	Sputnik 1	10/04/57
Payload recovery	Discoverer 13	08/10/60	Earth escape spacecraft	Luna 1	01/02/59
			Lunar impact	Luna 2	09/12/59
			Orbital platform launch	Sputnik 5	02/12/61
Synchronous satellite	Syncom 2	07/26/63	Venus flyby	Venera 1	02/12/61
Hydrogen rocket orbited	Centaur 2	11/27/63	Mars flyby	Mars 1	11/02/62
Docked spacecraft maneuver	Gemini 10-Agena	07/18/66	Venus impact	Venera 3	11/16/65
			Lunar soft landing	Luna 9	01/31/66
Lunar-velocity reentry	Apollo 4	11/09/67	Lunar orbiter	Luna 10	03/31/66
Constant deceleration reentry	Apollo 8	12/21/68	Automatic docking	Kosmos 186/188	10/27-29/67
Mars orbit	Mariner 9	05/30/71	Recovery, lunar payload	Zond 5	09/21/68
Jupiter flyby	Pioneer 10	03/03/72	Skip reentry lunar payload	Zond 6	11/10/68
Solar system escape	Pioneer 10	03/03/72			
Venus/Mercury flyby	Pioneer 10	11/03/73	Venus soft landing	Venera 7	07/17/70
Jupiter/Saturn flyby	Pioneer 11	04/05/73	Mars impact	Mars 2	05/19/71
Libration point halo orbit	ISEE 3	08/12/78	Mars soft landing	Mars 3	05/28/71
			Venus orbit	Venera 9	06/18/75
			Automatic propellant transfer	Progress 1	01/20/78
Auxiliary Power Systems			**Auxiliary Power Systems**		
Solar cells	Vanguard 1	03/17/58	Battery power	Sputnik 1	10/04/57
Isotope power	Transit 4A	06/29/61			
Nuclear reactor in orbit	Snapshot 1	04/03/65			
Fuel cell	Gemini 5	08/21/65			

CHAPTER THREE: SUPPORTING RESOURCES FOR SPACE FLIGHT

The ability of the two leading space powers to perform depends in the short run on the availability of existing resources to support such flights. These consist of finances, manpower, laboratories, factories, launch sites, tracking facilities, and launch vehicles. This section examines these categories to the extent data are available.

A. SPACE EXPENDITURES OF THE U.S. AND U.S.S.R.

The United States by September 1981 had spent about $138 billion total since the begining of the space program on space work in the several agencies of Government involved. These expenditures reached a previous peak of $7.7 billion in FY 1966, and in this fiscal year (1982) should be about $10.5 billion. Therefore, at the peak, this country was spending close to one percent of gross national product, and today it is spending about 1/3 of one percent. (These are current dollars unadjusted for inflation.)

The Soviet Union does not publish space budget data. Because they fly a greater weight of hardware, one could assume that their program is at least of the same magnitude as that of the United States at its former peak, and may be larger. Their gross national product is thought to be about half that of the United States, and therefore they probably spend about two percent of their gross national product on space.

International comparisons of this nature are notoriously difficult to make, and one should avoid the temptation to convert such crude estimates into ruble or dollar equivalents.

B. MANPOWER

In the United States, the National Aeronautics and Space Administration (NASA) program alone at its peak employed about 400,000 people (with 7 percent of these on the NASA payroll), but now has dropped to about 134,000. There were probably about 600,000 people at the peak employed in total U.S. space work. This figure does not include the indirect beneficiaries of the space program from the multiplier effects of these expenditures, nor does this figure emphasize the dependence of some regions upon space expenditures.

The Soviet Union does not disclose how many people are employed in their space work. The productivity of this work force in comparison with that of the United States is not known, either. One would like to think our productivity is higher, but some Soviet approaches to space development may be simpler than ours, which incorporate very extensive testing and duplicative facilities in our industry. The Soviet work force may be close to 600,000 people because their effort today seems to be at least equal to our 1966 peak.

C. SPACE LABORATORIES AND FACTORIES

The United States has several major NASA development centers, and other facilities operated by the Air Force and the Department of Energy. The private aerospace industry has a widespread industrial base capable of building and testing our hardware. However, the reduction of manpower at work in the space industry by more than one half has dispersed many of the trained teams needed to man these facilities, and any resumption of full scale efforts to utilize the physical plant could not come immediately.

The Soviet Union does not allow visits to many of its development facilities and no real measure of their total capacity is available in the public domain.

We are aware of the existence of many technical and scientific institutes, and have heard of a special space city in Kazakhstan (Leninsk?) where it is believed major assembly work is done. There is no reason to believe their total aerospace industry is as fully equipped as that of the United States, because of their tendency to do more testing in flight compared with the United States. On the other hand, missiles of somewhat similar capabilities, but with different design philosophies, appearing in Moscow parades suggest the existence of more than one design and development team for space work just as in Soviet aviation. Early in 1979, reports were circulating that there are five design bureaus for missiles and launch vehicles alone.

D. LAUNCH SITES

The United States has its major launch site for manned, lunar, planetary, and communications satellites at Cape Canaveral in Florida. It has a second important site for polar orbit military support flights and most weather and navigation launchings on the California coast at Vandenberg Air Force Base. A third minor site for small payloads is at Wallops Island, Virginia. Short-range vertical testing also is done at White Sands, New Mexico.

The Soviet Union has developed launch sites amazingly like the United States pattern. Their major site for manned, lunar, planetary, and some communications satellites, plus other developmental work, is near Tyuratam and

Leninsk in Kazakhstan. They call it the Baykonur Cosmodrome, but it is about 370 kilometers from the town of Baykonur. A second, largely military operational site, but also used for navigation, communication, and weather satellites, is near Plesetsk in the arctic north of Moscow. The third site is more modest, near Kapustin Yar on the Volga, south of what used to be Stalingrad (now Volgograd). It launches vertical probes (like White Sands) and small orbital payloads (like Wallops Island).

Each country seems to be adequately equipped with launch pads and ground support. Of course, as new vehicle systems come along, these require additional specialized facilities. The Soviet Union does not permit routine visits to its launch sites, and General de Gaulle with his personal physician (in 1966) and President Pompidou (in 1970) were the only known Westerners to have visited Tyuratam until 1975, when a few Americans had a limited glimpse of this base. Eastern European, Swedish, and Indian scientists have been allowed to attend launches of their payloads at Kapustin Yar, Plesetsk, and Tyuratam (in the case of countries supplying cosmonauts).

Table 3 summarizes the number of launch successes and resulting payloads from all sites of the world through 1981.

TABLE 3 — Worldwide Summary of Successful Space Launches by Site 1957-1981

Place	Earth Orbit	Lunar or Escape	Total
Plesetsk, Russia	813		813
Tyuratam, Kazakhstan	500	53	553
Vandenberg AFB, California	436		436
Cape Canaveral, Florida	262	58	320
Kapustin Yar, Russia	71		71
Wallops Island, Virginia	18		18
Uchinoura, Japan	12		12
Shuang Cheng-Zi, China	9		9
Kourou, Guyana	9		9
Indian Ocean Platform, Kenya	8		8
Tanegashima, Japan	8		8
Hammaguir, Algeria	4		4
Woomera, Australia	2		2
Sriharikota, India	2		2
Total	2,154	111	2,265

E. TRACKING FACILITIES

As an outgrowth of the IGY period, the United States created a worldwide tracking system with the cooperation of many other countries. This has been upgraded to a much higher capacity to meet the needs of Apollo as well as other programs. For U.S. deep space work, it has large 34- or 64-meter diameter dish antennas in California, Australia, and Spain which supported the lunar portion of Apollo and support distant planetary flights. Even with all these facilities, its system has had to be supplemented with tracking ships and special electronic-systems aircraft working in conjunction with satellites used to relay data on a real-time basis. Data relay satellites will perform most of these functions in the future.

The Soviet Union claims to have a nationwide tracking system, and the great spread of their country (about 2-1/2 times that of the United States) gives them a good systems start without leaving their own territory. There have been occasional press reports of Soviet efforts to put some tracking facilities into other countries such as in Africa or in Cuba. Their principal deep space tracking facility is in the Crimea and was visited over 20 years ago by Sir Bernard Lovell of the United Kingdom who headed the Jodrell Bank radio telescope facility. The military flight control center at the same Crimean location was visited by some American children under the auspices of the Young Pioneers in 1976.

Primarily, the Soviet Union accepts certain constraints to their space operations, and relies on ships to fill in gaps. Eleven ships have been named as assigned to the Soviet Academy of Sciences for space work, and often these are described as scattered around the world for space support purposes. Other tracking ships, not identified as under Academy control, have been pictured in the press and seem to be associated primarily with military missile tests, but could support space work as well. The most impressive tracking ship was the Kosmonavt Vladimir Komarov, used for lunar support work in the tropical waters of the Western Atlantic Ocean. It is frequently in Havana harbor. Now it is outclassed by the larger Akademik Sergey Korolev, and much larger Kosmonavt Yuriy Gagarin. For support of manned flights, one ship typically anchors off Nova Scotia. Soviet Molniya satellites relay information between tracking ships and the U.S.S.R. The principle of launch constraints is to make flights only at times and places which will be in view of Soviet tracking

stations at critical periods during the flight, and at other times to do without tracking, storing on tape in the space craft some data for later replay. The Kosmonavt Vladislav Volkov, first of four new tracking ships, entered service in 1977, followed by the Kosmonavt Pavel Belyayev, Kosmonavt Georgiy Dobrovolskiy, and Kosmonavt Viktor Patseyev, retiring some of the earlier ships.

F. LAUNCH VEHICLES

The United States has used launch vehicles scaled to lift payloads from as light as nine kilograms up to the Saturn V which could carry over 136,000 kilograms to low Earth orbit. In its manned programs, the Mercury spaceship (weighing about 1,360 kilograms) was launched to orbit by Atlas. The Gemini (weighing about 3,630 kilograms) was launched by Titan II. The first manned Apollo flight was about 20,410 kilograms, and was put up by Saturn I B. The lunar version Apollos, launched by Saturn V, were about 52,600 kilograms in the vicinity of the Moon. (For any launch vehicle, the farther the orbit is from the Earth, the greater the velocity required to get there and the smaller the payload. This is why Saturn V carries much less to the Moon than to Earth orbit.)

In 1957 the Soviet Union started to use its original ICBM, with an orbital lift capacity of 1,360 kilograms. The same basic (A) vehicle is in use today with upper stages added to improve performance. These upper stages permitted the launch of about 450 kilograms to the Moon in the first Luna series, and about 1,500 kilograms in the second Luna series. The early Luna-type launch rocket also was able to put up Vostok manned craft of 4,700

kilograms. The weight of Soyuz is about 6,575 kilograms still using this same basic launch vehicle with improved staging. Their Proton (D) launch vehicle has been demonstrated to carry 20,000 kilograms to Earth orbit. Its circumlunar capacity should be on the order of 4,820 kilograms; and used to Mars, it carried 4,650 kilograms. The very large Soviet (G) vehicle confidently predicted by NASA officials over a decade ago has not yet been launched and may have been retired after major launch failures. Lesser Soviet launch vehicles (B, C, and F) account for other unmanned programs.

Table 4 summarizes world-wide use of basic vehicles for successful launches to Earth orbit and beyond, through 1981.

TABLE 4 -- Number of Successful Launches to Earth Orbit and Beyond by Basic First Stage, 1957-1981

Name	Nationality	Vehicle Origin	Number
Sapwood (A)	USSR	missile (SS-6)	873
Thor	USA	missile	360
Skean (C)	USSR	missile (SS-5)	244
Atlas	USA	missile	182
Sandal (B)	USSR	missile (SS-4)	144
Titan	USA	missile	130
Scarp (F)	USSR	missile (SS-9)	103
Proton (D)	USSR		73
Scout	USA		72
Saturn 5	USA		13
Saturn 1	USA		13
Mu	Japan		11
"N"	Japan	missile (Thor)	8
FB-1	China	missile (CSS-X4)	7
Diamant B	France		6
Redstone	USA	missile	4
Jupiter	USA	missile	4
Diamant	France		4
Vanguard	USA		3
Ariane	ESA		3
Long March 1	China	missile (CSS-2)	2
SLV-3	India		2
STS	USA		2
Lambda	Japan		1
Black Arrow	U.K.		1
Total.....			2,265

It is argued in the Western World that the Soviet Union sized their first ICBM before the thermonuclear breakthrough in weaponry allowed light weight hydrogen bomb warheads. Hence, it ended up with a large and uneconomic vehicle on its hands, while the United States was able to scale down the design size of Atlas and Titan missiles because of reductions in warhead weight. Whether this assessment is right or not, the consequence has been helpful to the Soviet space program. While the United States was building its IGY program around a 9-kilogram Vanguard, they were building a 1,327-kilogram Sputnik 3, and planning to do even more on lunar flights.

Until the Saturn family appeared in service, at each stage the Soviet Union was equipped with larger launch vehicles by far. The repetitive use of the standard (A) vehicle probably gave it good reliability. It is rugged, has a first stage of five sets of tanks, four of which fall away from the core vehicle early in flight. Each of the five segments has four rocket nozzles, plus separate steering nozzles.

By Soviet accounts, several of their launch vehicles use liquid oxygen and a kerosene derivative for the first stages (as do many of those of the United States), and use fairly conventional storable fuels for upper stages. There is no sign of a secret breakthrough in fuels, but their engines are run at a relatively high pressure, increasing efficiency.

The United States has developed solid-fuel rockets mostly for military missile purposes, and certain space upper stages. The small Scout rocket is solid fuel in all stages, and strap-on boosters of solid fuel are used with Titan IIIC, D, & E, and Augmented Thrust Thors.

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The Soviet Union began to put large solid rocket missiles into its Moscow parades only in the last 15 years or so, well behind use of such rockets in the United States. These have some missile use, but there is no clear sign that solid-fuel rockets have been used for Soviet space purposes.

The United States experimented with components for a nuclear rocket as an upper stage for Saturn. A solid core reactor would heat hydrogen to be expelled from the nozzle. Despite this long time development effort, the work has now been cancelled as an economy move.

The Soviet Union could be developing a nuclear rocket, but so little has been said to date by them in this regard that any opinion on the subject would be highly speculative. Probably it has a low priority today.

The Russians have issued publicity on electric rockets. These are used operationally for station-keeping in ocean electronic ferret space craft. They have not yet been used for deep space acceleration of payloads.

Looking at the upper range of national capabilities, the Saturn V clearly has been the best operational weight lifter in the world. The 3.4 million-kilogram-thrust Saturn V may be challenged by a Soviet vehicle in the 4.5 to 6.4 million-kilogram-thrust class unless this rocket, suspected to have failed three times, has been permanently retired. In 1981, however, the U.S. Department of Defense included a booster of this size in its list of impending Soviet accomplishments in the publication Soviet Military Power. If such a vehicle is introduced, it would not necessarily be as much larger in payload capacity as the figures imply because Saturn V used liquid hydrogen for fuel

in its upper stages, and there is no firm evidence the Soviet Union has switched to high energy fuel, although such a switch could come at any point.

CHAPTER FOUR: MANNED FLIGHT COMPARISONS

The preceding sections have already touched on the changing nature of the "race" between the two space powers. Through the Voskhod program, every advantage remained with the Soviet Union. During Gemini, one "first" after another came to the United States along with a strong lead in total orbital experience until 1978. Apollo moved more rapidly than any Soviet corresponding effort, especially because at this time a Soviet launch vehicle capable of supporting a manned lunar landing had not orbited. But the Soyuz family of manned craft, with two compartments for men, may prove able to serve usefully as ferries to orbit, as components in elementary space stations, and possibly even as part of a future lunar landing system. Discussions of U.S.-Soviet comparisons frequently bring questions, of which several can be posed:

A. HOW TRUE ARE STORIES OF COSMONAUT DEATHS?

Although there is always the possibility of an accident close to the launch pad of which we would have no knowledge, the odds are overwhelming that the only Soviet cosmonauts killed in space flight so far are Komarov in 1967, and Dobrovolskiy, Volkov, and Patseyev in 1971. This is because the Russians have followed a conservative approach to manned flight with heavy vehicles allowing much redundancy in equipment. New types of manned flights have been preceded by unmanned tests in the same pattern. Flights are supported by world-wide dispositions of tracking and rescue ships. Private

word to other nations has been passed in Moscow before flights. Live television of the men in orbit has been the general rule.

With all this care and its known pattern of success, we are asked by those who believe many Russians have died in orbit in effect to accept the existence of a second Soviet manned flight program run with reckless abandon which often kills the flight crews. These purported failure flights, often detailed irresponsibly in the press with names and dates to make the unproven data look convincing, apparently would be conducted without advance warning, without tracking ships, without television, and use different models of larger, untried ships which always kill their crews or leave them stranded in orbit. Yet the "flights" cannot be detected by the same U.S. tracking systems that usually find even chance pieces of space debris at the altitudes manned flights occur. This is hardly credible.

B. DO THE RUSSIANS FAKE THEIR FLIGHTS?

In general, the Soviet Union seems to find that real successes which can be tracked and monitored by the Western World are more effective propaganda than inventing unreal flights which might fool the public briefly but would not impress governments with tracking facilities.

The Russians do not give many details in advance of their flights, so that when successes are less than complete they have less to explain. They usually claim that all mission objectives have been met when in fact this may not be the case; but in the absence of a preflight statement, it would be hard to disprove what they say.

One area in which they were especially subject to attack for faking related to the space walk by Leonov. Some specialists thought the pictures released had been simulated or doctored. Actually, in a number of cases, a review of the original Soviet film shows it used such language as "Here is a simulation . . . ," and this description somehow had been overlooked by the time other people in the Western World examined the questionable film, and quite correctly found some portions of it were not the real thing. Simulations were used where no camera could be positioned to capture the real event as it happened.

C. HOW DO THE PUBLICITY POLICIES OF THE TWO COUNTRIES COMPARE?

The NASA (civilian) part of the U.S. program is generally run on a very open basis with the press at launches and most questions about flights answered both before they occur and after they are over. There is less openness in the Department of Defense space launchings, most of which are not given names or purpose, advance notice, or published results.

The Soviet Union holds to a minimum advance notice of flights, limits information on the bulk of their flights, but at least makes a prompt announcement, assigns a name, and gives orbital parameters for all flights which are successful in reaching some kind of an orbit which looks reasonable. All are described as scientific in purpose and successful in some degree. While a reporter in the United States can query NASA for more details of NASA flights, reporters rarely are able to gain elucidating details through questioning Soviet officials about their flights.

D. ACCOMPLISHMENTS OF MANNED FLIGHTS

The Apollo and Skylab programs gave the United States a proven capacity to stay in orbit with multiple-man crews up to 84 days, to adjust orbits repeatedly, to rendezvous successfully by several means, to dock and transfer crews, and to stay for hours outside the spaceship in protective suits. The men occasionally felt discomfort, but were able to perform basic tasks. NASA began flights with a reduced-pressure pure oxygen breathing systems. It has made occasional use of television from the spaceship to Earth, and by the time of Apollo 15 had reached a high level of perfection in color pictures even from a roving vehicle on the Moon. In 1981, a new era of U.S. manned space activities began with two launchings of the reusable space shuttle system.

Soyuz and Salyut have extended the Soviet manned capabilities as well. Soyuz is said to be capable of flying up to 1,300 kilometers altitude, and to provide a stay time of 30 days. So far, no Soviet ship with men on board has flown that high, although unoccupied ships have made circumlunar flights. Maximum stay time has been 185 days with Salyut 6. But the Russians have demonstrated both a fully automatic and partly manual rendezvous and docking capability, and have transferred crews in orbit from one ship to another. They have consistently used an atmosphere equivalent to normal air at sea-level pressure, and have used television from orbit extensively since their first manned flight. Now they can operate with two separate ships linked to a station at the same time, either with two crews or to deliver propellants, air, water, and replacement parts.

Perhaps the most spectacular new Soviet event in 1979 was the deployment of a 10-meter radio telescope concave dish at the after end of Salyut 6 which had been brought up unassembled in supply ship Progress 7. At the end of the mission, the Soyuz 32/34 crew had to go outside in space suits to free the balky antenna which "refused" to float off when detached.

In 1980, the greatly improved Soyuz-T class of ferry, under development for several years, came into use for human crews. Almost completely rebuilt with improved life support, better electric power supply, unified propulsion, and an on-board computer/navigation system, Soyuz-T has restored the pre-1971 capability to carry a 3-man crew. In 1981, the Soviets announced that the original Soyuz craft would no longer be used now that Soyuz T is operational.

E. SUMMARY TABLE OF MANNED FLIGHTS

The table which follows gives the principal results and characteristics of each U.S. and Soviet manned flight to date:

TABLE 5

Summary List of Manned Space Flights

Launch Date	Vehicle Name	Crew	Weight (kgs)	Duration (hrs.,min.)	Orbits	Highest Altitude (kms)	National Cumulative Manhours
1961							
Apr. 12	Vostok 1	Gagarin	4,725	1:48	1	327	1:48
May 5	MR-3	Shepard	1,290	:15	--	188	:15
July 21	MR-4	Grissom	1,286	:16	--	190	:31
Aug. 6	Vostok 2	Titov	4,731	25:18	17	257	27:06
1962							
Feb. 20	MA-6	Glenn	1,355	4:55	3	261	5:26
May 24	MA-7	Carpenter	1,349	4:56	3	269	10:22
Aug. 11	Vostok 3	Nikolayev	4,722	94:25	64	251	121:31
Aug. 12	Vostok 4	Popovich	4,728	70:59	48	254	192:30
Oct. 3	MA-8	Schirra	1,373	9:13	6	283	19:35
1963							
May 15	MA-9	Cooper	1,376	34:20	23	267	53:55
June 14	Vostok 5	Bykovskiy	4,720	119:06	81	222	311:36
June 16	Vostok 6	Tereshkova	4,713	70:50	48	233	382:26
1964							
Oct. 12	Voskhod 1	Komarov Yegorov Feoktistov	5,320	24:17	16	409	455:17
1965							
Mar. 18	Voskhod 2	Belyayev Leonov	5,682	26:02	17	490	507:21
Mar. 23	GT-3	Grissom (2) Young	3,225	4:53	3	224	63:41
June 3	GT-4	McDivitt White	3,574	97:56	66	296	259:33
Aug. 21	GT-5	Cooper (2) Conrad	3,605	190:55	128	346	641:23
Dec. 4	GT-7	Borman Lovell	3,663	330:35	220	327	1,302:33
Dec. 15	GT-6	Schirra (2) Stafford	3,546	25:51	17	304	1,354:15

TABLE 5 (continued)

Launch Date	Vehicle Name	Crew	Weight (kgs)	Duration (hrs.,min.)	Orbits	Highest Altitude (kms)	National Cumulative Manhours
1966							
Mar. 16	GT-8	Armstrong Scott	3,788	10:41			
June 3	GT-9	Stafford (2) Cernan	3,750	72:21			
July 18	GT-10	Young (2) Collins	3,741	70:47			
Sept. 12	GT-11	Conrad (2) Gordon	3,860	71:17			
Nov. 11	GT-12	Lovell (2) Aldrin	3,763	94:35			
1967							
Jan. 27	AS-204	Grissom (3) 1/ White (3) 1/ Chaffee 1/	20,412	[Not a space flight, but date of fatal fire on pad during test preliminary to later scheduled flight.]			
Apr. 23	Soyuz 1	Komarov (2) 1/	6,450	26:37	18	224	533:58
1968							
Oct. 11	Apollo 7	Schirra (3) Eisele Cunningham	20,569	260:09	174	449	2,774:04
Oct. 26	Soyuz 3	Beregovoy	6,575	94:51	64	252	628:49
Dec. 21	Apollo 8	Borman (2) Lovell (3) Anders	43,663	147:01	2(Earth) 10 (Moon)	400,000	3,215:07
1969							
Jan. 14	Soyuz 4	Shatalov (Yeliseyev) (Khrunov)	6,625	71:23*	48	253	795:50
Jan. 15	Soyuz 5	Volynov Yeliseyev Khrunov	6,585	72:56	49	253	868:46

1/ Fatality
* Crew duration for two transferring, 47:49 each.

TABLE 5 (continued)

Launch Date	Vehicle Name	Crew	Weight (kgs)	Duration (hrs.,min.)	Orbits	Highest Altitude (kms)	National Cumulative Manhours
Mar. 3	Apollo 9	McDivitt (2) Scott (2) Schweickart	43,185	241:01	162	504	3,938:10
May 18	Apollo 10	Stafford (3) Young (3) Cernan (2)	48,638	192:03	2 (Earth) 31 (Moon)	400,000	4,514:19
July 16	Apollo 11	Armstrong (2) Collins (2) Aldrin (2)	49,698	195:19	2 (Earth) 30 (Moon)	400,000	5,100:16
Oct. 11	Soyuz 6	Shonin Kubasov	6,577	118:42	80	230	1,106:10
Oct. 12	Soyuz 7	Filipchenko Gorbatko Volkov	6,570	118:41	80	226	1,462:13
Oct. 13	Soyuz 8	Shatalov (2) Yeliseyev (2)	6,646	118:50	80	256	1,699:53
Nov. 14	Apollo 12	Conrad (3) Gordon (2) Bean	49,804	244:36	2 (Earth) 45 (Moon)	400,000	5,834:04
1970 Apr. 11	Apollo 13	Lovell (4) Haise Swigert	49,990	142:55	2 (Earth) 1 (Moon)	400,000	6,262:49
June 1	Soyuz 9	Nikolayev (2) Sevastyanov	6,500	424:59	286	267	2,549:51
1971 Jan. 31	Apollo 14	Shepard (2) Roosa Mitchell	46,347	216:02	2 (Earth) 34 (Moon)	400,000	6,910:55
Apr. 19	Salyut	(Occupied by Soyuz 11 crew)	18,600?	---	---	282	---

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TABLE 5 (continued)

Launch Date	Vehicle Name	Crew	Weight (kgs)	Duration (hrs.,min.)	Orbits	Highest Altitude (kms)	National Cumulative Manhours
Apr. 22	Soyuz 10	Shatalov (3) Yeliseyev (3) Rukavishnikov	6,575?	47:46	32	246	2,693:09
June 6	Soyuz 11	Dobrovolskiy 1/ Volkov (2) 1/ Patsayev 1/	6,575?	570:22	385	282	4,404:15
July 26	Apollo 15	Scott (3) Irwin Worden	52,759	295:12	2 (Earth) 74 (Moon)	400,000	7,796:31
1972							
Apr. 16	Apollo 16	Young (4) Duke	51,571	265:51	2 (Earth) 65 (Moon)	400,000	8,594:04
Dec. 7	Apollo 17	Cernan (3) Schmitt Evans	51,808	301:52	3 (Earth) 75 (Moon)	400,000	9,499:40
1973							
May 14	Skylab 1	(Occupied by successive crews)	89,439	---	---	440	---
May 25	Skylab 2	Conrad (4) Kerwin Weitz	30,803	672:50	433	440	11,518:10
July 28	Skylab 3	Bean (2) Garriott Lousma	30,694	1,427:09	919	440	15,799:37
Sept. 27	Soyuz 12	Lazarev Makarov	6,575?	47:16	32	345	4,498:47
Nov. 16	Skylab 4	Carr Gibson Pogue	31,232	2,017:16	1,298	442	21,851:25
Dec. 18	Soyuz 13	Klimuk Lebedev	6,575?	188:55	127	273	4,876:37

1/ Fatality

TABLE 5 (continued)

Launch Date	Vehicle Name	Crew	Weight (kgs)	Duration (hrs.,min.)	Orbits	Highest Altitude (kms)	National Cumulative Manhours
1974							
June 24	Salyut 3	(Occupied by Soyuz 14 crew)	18,900?	---	---	276	---
July 3	Soyuz 14	Popovich (2) Artyukhin	6,570	337:30	252	277	5,631:37
Aug. 26	Soyuz 15	Serafanov Demin	6,570?	48:12	32	275	5,728:01
Dec. 2	Soyuz 16	Filipchenko (2) Rukavishnikov (2)	6,570?	142:24	96	225	6,012:49
Dec. 26	Soyuz 4	(Occupied by Soyuz 17, 18 crews)	18,900	---	---	361	---
1975							
Jan. 10	Soyuz 17	Gubarev Grechko	6,570	709:20	466	361	7,431:29
Apr. 5	Anomaly	Lazarev (2) Makarov (2)	6,570?	:20	---	---	7,432:09
May 24	Soyuz 18	Klimuk (2) Sevastyanov (2)	6,570?	1,511:20	993	384	10,454:49
July 15	Soyuz 19	Leonov (2) Kubasov (2)	6,800	142:31	96	225	10,739:51
July 15	Apollo	Stafford (4) Slayton Brand	14,743	217:28	145	225	22,303:49
1976							
June 22	Salyut 5	(Occupied by Soyuz 21, 24 crews)	18,900?	---	---	---	---
July 6	Soyuz 21	Volynov (2) Zholobov	6,570?	1,182:24	790	281	13,104:39
Sept. 15	Soyuz 22	Bykovskiy (2) Aksenov	6,570?	189:54	127	280	13,484:17
Oct. 14	Soyuz 23	Zudov Rozhdestvenskiy	6,570?	48:06	32	275	13,580:39

TABLE 5 (continued)

Launch Date	Vehicle Name	Crew	Weight (kgs)	Duration (hrs.,min.)	Orbits	Highest Altitude (kms)	National Cumulative Manhours
1977							
Feb. 7	Soyuz 24	Gorbatko (2) Glazkov	6,570?	425:23	285	281	14,431:25
Sept. 29	Salyut 6	(Occupied by Soyuz 26, 27, 28, 29, 30, 31, 32, 35, 36, 37, 38, T2, T3, T4, 39, 40 crews)	18,900?	---	---	411	---
Oct. 9	Soyuz 25	Kovalenok Ryumin	6,570?	48:46	32	353	14,528:57
Dec. 10	Soyuz 26	Romanenko Grechko (2)	6,570?	898:06*	590	354	16,325:09
1978							
Jan. 10	Soyuz 27	Dzhanibekov Makarov (3)	6,570?	1,558:53**	1,024	350	19,442:55
Mar. 2	Soyuz 28	Gubarev (2) Remek (Cezechoslovakia)	6,570?	190:17	125	353	19,823:29
Jun. 15	Soyuz 29	Kovalenok (2) Ivanchenkov	6,570?	1,911:23***	125	368	23,646:15
Jun. 27	Soyuz 30	Klimuk (3) Hermaszewski (Poland)	6,570?	190:04	125	360	24,026:23
Aug. 26	Soyuz 31	Bykovskiy (3) Jahn (German Dem. Rep.)	6,570?	1,628:14****	1,070	354	27,282:51

* Crew duration 2314:00
** Crew duration 142:59
*** Crew duration 3350:48
**** Crew duration 188:49

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TABLE 5 (continued)

Launch Date	Vehicle Name	Crew	Weight (kgs)	Duration (hrs.,min.)	Orbits	Highest Altitude (kms)	National Cumulative Manhours
1979							
Feb. 25	Soyuz 32	Lyakhov Ryumin (2) (Returned unmanned)	6,570?	2,596:24*	1,711	371	32,475:39
Apr. 10	Soyuz 33	Rukavishnikov (3) Ivanov (Bulgaria)	6,570?	47:01	31	353	32,569:41
June 6	Soyuz 34	(Launched unmanned, returned Soyuz 32 crew)	6,570?	1,770:17	1,153	411	35,778:05
1980							
Apr. 9	Soyuz 35	Popov Ryumin (3)	6,570?	1,321:29**	868	369	38,421:03
May 26	Soyuz 36	Kubasov (3) Farkas (Hungary)	6,570?	1,580:54***	1,040	355	41,582:51
June 5	Soyuz T-2	Malyshev Aksenov (2)	7,000?	94:41	62	350	41,772:13
July 23	Soyuz 37	Gorbatko (3) Pham Tuan (Viet Nam)	6,570?	1,911:17****	1,257	355	45,594:47
Sept. 18	Soyuz 38	Romanenko (2) Tamayo Mendez (Cuba)	6,570?	188:43	124	350	45,972:13
Nov. 27	Soyuz T-3	Kizim Makarov (4) Strekalov	7,000?	307:08	204	370	46,893:37

* Crew duration 4,200:36
** Crew duration 4,436:12
*** Crew duration 188:46
**** Crew duration 188:42

TABLE 5 (continued)

Launch Date	Vehicle Name	Crew	Weight (kgs)	Duration (hrs.,min.)	Orbits	Highest Altitude (kms)	National Cumulative Manhours
1981							
Jan. 24	Soyuz T-4	Kovalenok (3) Savinykh	7,000?	1,794:38	1,196	358	50,482:13
Mar. 22	Soyuz 39	Dzhanibekov (2) Gurragcha (Mongolia)	6,570?	186:43	125	358	50,855:39
Apr. 12	STS 1	Young (5) Crippen	98,658	54:21	36	275	22,612:31
May 14	Soyuz 40	Popov (2) Prunariu (Romania)	6,570?	188:41	126	358	51,233:01
Nov. 12	STS 2	Engle Truly	103,811	54:13	36	251	22,720:57

CHAPTER FIVE: MILITARY VS. CIVILIAN SPACE ACTIVITIES

Questions are frequently raised as to the differences of purpose, organization, and use of space programs in the Soviet Union and the United States. The most frequently raised issues are discussed below.

A. MILITARY VERSUS CIVIL SPACE PURPOSES

For the most part there seems to be little difference between the Soviet and U.S. space programs as to general purpose and direction (with two major exceptions to be noted later). Both are broadly based, with elements of scientific exploration, technology development, national image building, practical applications, and military support services. About 57% of U.S. flights have been conducted for the Department of Defense, with 44% for strictly military purposes. About 66 percent of successful Soviet flights have been for strictly military purposes. About 49 percent of current U.S. space funds are spent for the programs of DOD which are less expensive than those of NASA because more of them are for routine operations rather than new development. Corresponding breakdowns for the Soviet total program are harder to establish because of their secrecy of budget data, and their claim that all flights are scientific. Yet a very considerable number of their flights and research give convincing indications of serving military purposes.

B. MANAGEMENT OF SPACE PROGRAMS

Under the terms of the National Aeronautics and Space Act of 1958, the principal portion of the U.S. space program is run by a civilian organization, the National Aeronautics and Space Administration. Another major segment is operated by the Department of Defense using the Air Force as its executive agent, with emphasis on supplying military support, or doing the R&D associated with military support. Lesser amounts of the program are scattered among other development or user agencies such as the Department of Energy (development), the Departments of Commerce, Transportation, Agriculture and Interior (users). A coordinating body, which operated from 1958 to 1973, the National Aeronautics and Space Council, has been disestablished.

Much less is known about the Soviet pattern of organization. The Russians have held secret even the names of their top space officials with very few exceptions. Nor are the exact names of all their space organizations known. The Soviet Academy of Sciences plays a role in planning a part of the program. The Soviet Strategic Rocket Forces conduct launches and apparently are responsible for supplying the launch vehicles. But the interfaces are obscure, and if there are construction and testing ministries in between, little is known of them.

C. POTENTIAL THREAT OF MILITARY FLIGHTS

United States policy has been that its military flights are nonaggressive. Many of its military flights are hardly distinguishable from flights conducted for civilian application purposes. Thus a message sent by satellite, or a

weather report from space observation, or navigational data to a ship, are technically neutral in character. Often these services are of a traditional nature, simply done more speedily or cheaply by space means. Whether such services are aggressive is in the mind of the user, and are not subject to scientific, absolute determination. In a philosophical sense, a businessman or a government civil department sending a message by satellite might be more "aggressive" than a military user sending data on personnel counts or number of wool socks in a warehouse somewhere.

Although the U.S. Government is reluctant to discuss the subject, careful observers of military space activities have a strong conviction that the most active development of military space flights lies in the area of Earth observation. President Johnson, speaking in Nashville, Tennessee on March 15, 1967, claimed in an "off-the-record" statement widely reported at the time that the dividends of military space operations to the United States were equal to ten times everything which had been spent on space. This implied savings in the defense budget over a ten year period on the order of $400 billion, because of more precise information about military and related activities all over the world. American analysts argue that sure information from space is one of the greatest safeguards against miscalculation by the major powers, and hence, in the absence of explicit international agreements for open skies and ground inspection, is a fair bargain in reducing the risks and costs stemming from erroneous impressions. President Carter on October 1, 1978 officially acknowledged the U.S. role in military photoreconnaissance from space.

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There is no doubt that the Soviet Union has a large and regular program of military support flights, including use of satellites for photographic observation, early warning, electronic listening, weather reporting, communications relaying, and ship navigation. Although these space services undoubtedly enhance Soviet military capabilities, in net balance they probably are to the advantage of the United States if surer knowledge between these two big powers makes each more cautious and less prone to error in estimates.

D. SPACE WEAPONS

Ever since the days of Sputnik 1, there has been public worry about bombs dropped from orbit. The potential threat is there, but it must be qualified by many practical considerations. At the present time, the disadvantages of space-based weapons are sufficiently great that the United States has chosen not to develop them, and found little difficulty in agreeing to a treaty to ban weapons of mass destruction from orbit and all military activities from other celestial bodies.

The Soviet Union is also a party to this same treaty and reasonable analyses are fairly convincing that up to this time the Soviet Union has not placed nuclear bombs in orbit. Some of the logic runs as follows:

A bomb in orbit must be called down by signal, and on a particular orbit will fall close only to a selected path defined by the orbit, so that hitting a planned target is possible only at certain hours or days, and in a sudden emergency might not be near a useful target.

A bomb in orbit may be subject to malfunction because Soviet spacecraft have been notoriously short-lived in their reliability. A malfunctioning bomb might fall to destroy a Soviet city as well as one in an enemy country.

A bomb in orbit is less manageable than one in a silo at home or in a submarine, not only for reasons of maintenance, but also for command and control. If placed in orbit, it might be subject to spurious signals; and eventually the nuclear material might be wasted if the bomb ceased its functions, or the orbit decayed to let it fall at random, even with a safeguard against detonation.

A bomb in fixed orbit can be precisely located, and hence intercepted by another space power.

One or a few bombs might be placed in orbit secretly or in disguised form, but having only a few would not be decisive against a second strike capability by the target country. If done for terror purposes with publicity, then the Soviet Union would not only be avowedly breaking the space weapons treaty but would risk a preemptive strike by the United States if the threat were believed.

On the other hand, if a larger and possibly useful number of weapons were placed in orbit, the fact of such launches would quickly become evident to the radars, computers, and analysts in the United States, and the threat would be clear and require as positive a counter move as would a direct ICBM attack on this country. Such launchings would signal Soviet intentions with more warning time than would a surprise attack directly by ICBM's.

1. The Fractional Orbit Bombardment System -- FOBS

In one respect the Soviet Union has already heightened tensions by testing a fractional orbit bombardment system. This is not a technical violation of the treaty because there is no reason to suppose they would need to carry nuclear material on board the test flights, and the dummy warhead has flown less than one full orbit. The pattern has been to launch a satellite from the Soviet Union on a path avoiding the United States, and calling down the test warhead just before the end of the first orbit onto Soviet territory, while some minor debris and expended rocket casing stay in orbit for a few more hours before decaying.

From a Soviet point of view, FOBS has the advantage of complicating U.S. defenses. Although scientifically speaking the warhead is in orbit, in effect it is like an extended range ICBM capable of flying the long way around the world to bypass the normal ballistic missile early warning system (BMEWS) radar fences which point to the north. If flown by the usual shortest routes to the United States, it could do so with a depressed apogee compared with conventional ICBM's, so as to cut warning time to BMEWS because of the delayed detection brought by the curvature of the Earth hiding the presence of the low-flying warhead. Such flights in combat have disadvantages, however, including reduced accuracy on target if coming the long way around, and reduced payload by any route compared with the use of the same launch vehicle as an ICBM. The United States does not have a FOBS program because it does not regard it as necessary or desirable. The Russians obviously do, or did, for reasons not wholly clear. However, there have been no flights since 1971.

Perhaps another reason for not deploying such a Soviet system is the steadily improving U.S. capability to detect missile launchings from any quarter.

2. Antisatellites (Killer Satellites)

In 1964, President Johnson announced that the United States had at least a limited capability to intercept hostile satellites using missile systems based at Johnston and Kwajalein Islands in the Pacific. These would not have met all possible needs, but over the course of some days could have intercepted most satellites in sustained low orbit. These facilities are believed to have been shut down in 1975. The United States also once had a satellite orbital inspector program called Saint, which was abandoned before the first test flight. Today the United States is developing an air-launched antisatellite device using miniature homing vehicles which is expected to be flight tested in 1983.

The Soviet Union has a limited deployment of the Galosh ABM system, and probably also could intercept hostile satellites in about the same degree as the United States could have from its mid-Pacific installations.

Additionally, the Soviet Union, within its Kosmos series, has flown satellites which British observers suspect from their orbital characteristics are launched by the same SS-9 Scarp (F) vehicle also used for the Soviet FOBS. These flights usually are maneuvered in orbit, and in both 1968 and 1970, two successive flights made a reasonably close intercept of a target satellite and then were in turn exploded into many pieces of debris. Three single intercepts were flown in 1971. In the absence of Soviet announcements, an assessment

cannot be conclusive, but the suspicion remains that a capability to inspect and destroy satellites has been created. Flights resumed in 1976 using three target satellites and four interceptors. In 1977 there were also three target satellites and four interceptors. Interceptors have been flown in 1978, 1980, and two in 1981.

E. OCEAN SURVEILLANCE

Another part of the Soviet maneuverable satellite program using the F launch vehicle has been identified by DOD and by a British analyst as probably used for ocean surveillance by active radar able to penetrate clouds and darkness. When the main mission ends some weeks after launch, the craft separates into several parts with one segment fired into a higher orbit with a 600 year life, because of a nuclear power source contained in it. Confirmation of the power system came when malfunctioning Kosmos 954 fell in Canada on January 24, 1978 and spread radioactivity in a swath across the Northwest Territories. After the accident, no similar flights were made until April 1980.

A second category of ocean surveillance flights stays at a higher altitude and is not maneuvered upwards later. Speculation is that these are electronic ferrets, and do not use nuclear power, but use electric propulsion to maintain their orbit.

F. MUTUAL NON-INTERFERENCE

For the time being at least, it remains in the Soviet interest not to interfere actively with U.S. satellite flights just as it is U.S. policy not to interfere with theirs. The SALT I agreement included a provision for non-interference with "national technical means" for policing compliance. The first visible new threat to such reciprocity was the report of late 1975 that the Russians had begun probing U.S. military satellites with powerful laser beams. If true, this could lead to very destabilizing relations in space. A follow-up Department of Defense analysis was that Soviet gas pipeline fires accounted for the phenomena of temporary saturation of these space-borne sensors. If correct, that may be reassuring, although technologically the laser threat may be possible, and doubt in any question of signal interpretation is disturbing.

G. FRESH CONCERNS ABOUT MILITARY ACTIVITIES IN SPACE

The strength and variety of Soviet efforts related to military space interceptors have raised serious questions as to future Soviet intentions with regard to the principles of non-interference. The U.S. response has been two-fold: To develop U.S. interceptors to match the emerging Soviet capabilities; and to raise with the Russians the possibility of an agreement to put limits on the development or deployment of such systems. Three rounds of limitation talks were held in 1978 and 1979, with no concrete results.

So far, there has been no obvious move to extend the upward reach of Soviet interceptors above 2,000 kilometers toward the ten-to-fifteen-times-as-high orbits of the U.S. global positioning system, the early warning systems, and the geosynchronous communications satellites. Such an upward extension would be particularly alarming to U.S. authorities.

Another important development of 1978-80 was the sustained flow of stories and claims of continuing high priority efforts by the Russians to develop both space-based and ground-based beam weapons to kill satellites. Some experienced observers see convincing signs that facilities and experiments are well along while some distinguished scientists have implied that many of the claims can have no foundation in fact for reasons of physical laws. The trade press has reflected a real stirring in the U.S. defense community to support a wide range of equivalent U.S. technologies. The conclusion seems to be that both superpowers are exploring technical options, and while some approaches may fail, there are distinct possibilities that practical applications in space warfare will be found both for laser beams and for charged particle beams. Before the 1980's are over, these could have far-reaching effects on military power and the stability of arms control measures.

From the Soviet perspective, the advent of the U.S. space shuttle has raised concerns about U.S. military intentions in space. Three days after the first successful flight of the shuttle in April 1981, Soviet President Brezhnev made a speech in which he stressed the desire of the Soviet Union to use space for peaceful purposes. In August 1981, the Soviets introduced a draft treaty at the United Nations to ban weapons from space. The United

States took a dim view of this treaty, not only because the Soviet Union is the only country with an operational space weapons system, but because the language in the draft treaty seems directed specifically at the U.S. shuttle. The draft treaty, which has been referred to the U.N. Committee on Disarmament, would prohibit the deployment of weapons, inter alia, on "piloted space vessels of multiple use."

H. SUMMARY TABLE OF MILITARY VS. CIVILIAN SPACE FLIGHTS

The table which follows attempts to divide as meaningfully as possible, though still tentatively, the space flights of the two nations as to whether they are civilian or military in character:

TABLE 6

Approximate Comparison of United States and Soviet Successful Space Launchings -- Primarily Civil Oriented Versus Presumptively Military Oriented

	Primarily or Ostensibly Civil				Presumptively Specialized Military	
Year	NASA	DOD	U.S. Total	USSR	DOD	USSR
1957	0	0	0	2	0	0
1958	0	5	5	1	0	0
1959	5	0	5	3	5	0
1960	5	1	6	3	10	0
1961	10	0	10	6	19	0
1962	18	3	21	15	31	5
1963	10	2	12	10	26	7
1964	22	3	25	15	32	15
1965	24	11	35	23	28	25
1966	30	11	41	17	32	27
1967	25	8	33	20	24	46
1968	19	6	25	25	20	49
1969	21	3	24	19	16	51
1970	12	2	14	26	15	55
1971	14	7	21	23	10	60
1972	17	3	20	21	11	53
1973	12	3	15	28	8	58
1974	14	2	16	29	6	52
1975	18	3	21	29	7	60
1976	13	6	19	25	7	74
1977	13	2	15	29	9	69
1978	19	5	24	28	8	60
1979	7	5	12	27	4	60
1980	5	3	8	25	5	64
1981	11	2	13	39	5	59
TOTAL	344	96	440	488	338	949

To a degree, classification has been arbitrary, following the format of information used in table 7 of this report.

CHAPTER SIX: SPACE APPLICATION FLIGHTS

In the area of space applications, the United States has held a clear lead from the earlier days of the space program, and this experience has permitted this country to move ahead to more advanced systems while the Soviet Union is still working hard to catch up.

A. COMMUNICATIONS

The United States experimented with both civilian and military communication satellites, first with low-altitude pickup, tape storage, and replay systems, and also with passive reflectors of the balloon type. But now the pattern is well set to use satellites of increasing capacity each year, synchronous at about 35,880 kilometers altitude which to all intents and purposes stay at a fixed point over the Equator relative to the ground. Color TV can be relayed across oceans, and telephone and data relay capacity is growing rapidly, with a matching drop in costs of operation.

The Soviet Union has gone quite a different path. Following by some years the U.S. start, since 1965 they have put up a series of Molniya 1 satellites which are heavier than corresponding U.S. communications satellites. These Molniya 1's fly in an orbit inclined at 63 degrees to the Equator with a low point over the southern hemisphere, but a long linger time at the peak of the orbit in the northern hemisphere, so that each is in view of major Soviet ground terminals for about eight hours a day, including those at near polar latitudes harder to reach with equatorial satellite systems. Their high

power has permitted the establishment of relatively low-cost terminals to distribute TV programs from Moscow to outlying points, as well as carrying telephone and computer data traffic. By proper spacing of eight of these satellites in 12-hour semisynchronous orbits in orbital planes 45 degrees apart, it is possible to give full daily coverage, with each satellite traveling the same ground trace each day.

Now the Molniya 1's have been relegated to military service. These were followed first by Molniya 2 and now by Molniya 3 satellites (4 to a system) using higher frequencies to provide the prime service, arranged in planes 90 degrees apart. In 1974 for the first time the Russians put Kosmos 637 and then Molniya 1S-1 into 24-hour synchronous equatorial orbits. Late in 1975 the Statsionar plan of 24-hour synchronous satellites, was announced as expanding to eleven expected over the next five years. Raduga, the first Statsionar, was launched December 22, 1975. It has been followed in 1976 by Raduga 2 and Ekran 1, a television distribution satellite. In 1977, Raduga 3 and Ekran 2 were also placed in orbit. In 1978 Raduga 4 was placed in orbit and the first of a new system called Gorizont 1. In 1979, Ekran 3 and 4, Raduga 5, and Gorizont 2 and 3 were launched. In 1980 came Ekran 5 and 6, Raduga 6 and 7, and Gorizont 4. Raduga 8 and 9 and Ekran 7 were launched in 1981.

Military communications systems within the Kosmos program also are in place for theater tactical use and in store-dump mode worldwide. (Store-dump satellites receive messages, placing these on tape and replay them later on command.)

B. WEATHER REPORTING

The United States has an operational weather satellite system using the NOAA series in polar orbits and GOES satellites in geosynchronous orbits. World coverage is fairly good, including the ability of local stations to read the APT (automatic picture transmission) equipment on board many of these satellites for a "real time" view of local regional weather. There are also military weather satellites in orbit.

The Soviet Union also came late to this field compared with the United States. Only since 1966 have they distributed satellite-gathered weather pictures, and these spacecraft have had the disadvantage of a shorter useful life before electronic failure, compared to United States spacecraft. Their pictures have a higher resolution which may give more detail, but high resolution reduces the amount of daily coverage a satellite can give, with many smaller area pictures having to be fitted together for larger area views. On the other hand, the Soviet satellites more nearly resemble advanced U.S. Nimbus craft in terms of the wider variety of sensors carried and the experimental work underway which may open up new discoveries. In 1977, for the first time, a Soviet weather satellite was put into a retrograde, Sun-synchronous orbit (to take pictures at a constant local time), the pattern long favored for U.S. weather satellites. In addition to these Meteor weather satellites of lower altitude flights, weather cameras have been carried on some of the higher flying Molniya 1 satellites as well, so that a steerable camera at 40,600 kilometers can give wide area views like those taken by the

U.S. craft at similar altitudes. The Soviets had promised to provide a 24-hour synchronous weather satellite for the cooperative world system being created with the United States, Japan and Western Europe, but the flight has been delayed indefinitely.

C. NAVIGATION AND TRAFFIC CONTROL

The United States has a U.S. Navy operational navigation satellite system, originally called Transit, now renamed the Navy Navigation Satellite System. It operates through the passive reading on ships of Doppler shift in harmonic signals from the satellites, and the data are manipulated by a computer on board the ship in connection with broadcast data on the position of the satellite. It is not particularly suited to commercial economics, but it is highly effective for naval purposes. Commercial ships have been permitted to use the same system since 1967 if they care to invest in the necessary computer equipment. An improved version of Transit, called Nova, is now coming into use with the first launch in 1981. An even more ambitious global positioning system, ultimately to use 18 satellites, began operations in 1978 with the first four NAVSTAR Air Force satellites. Two more NAVSTARS were launched in 1980, but a launch attempt in 1981 failed because of a launch vehicle malfunction. These satellites are part of the NAVSTAR development program; the system is not expected to be operational until 1988. Future civilian systems are more likely to require the ship or aircraft to play an active

role by broadcasting signals to satellites, which will relay to a shore-based computer these data to find the ship or aircraft position, and this may serve in future traffic control systems as well. This has been tested in the ATS satellites.

The Soviet Union claims to have had an operational navigation satellite system for many years, but waited until 1978 to identify the first specific component, Kosmos 1000. A new label was applied at the Paris Air Show Soviet display of a navigation satellite--Taikada. However, many of the Kosmos missions are flown in ways which strongly suggest these are navigation satellites, probably linked with a passive ship system for naval purposes, which would seem a close parallel to the Transit system of the United States, even to using the same radio frequencies. Judgments as to quality are not possible in the absence of Soviet openness.

D. GEODESY AND MAPPING

The United States has flown many geodetic flights in the interest of tying together maps of different parts of the world and for basic scientific studies to understand better the true shape of the world. If there have been mapping flights as well, the results have not been published.

The Soviet Union professes an interest in both geodesy and mapping, but too few findings have been made available to judge how far along they are in comparison with the United States. Some known Kosmos flights have the right characteristics to support such missions.

E. EARTH RESOURCES

One of the most exciting new fields of space application is that of finding and managing Earth resources in many fields through use of satellites. It is expected that mineral deposits and oil fields can be found, and forest fires located. The location of diseased trees and agricultural crops may be identified, censuses of crops taken, snowfall and water status reported, fisheries run more efficiently, and many other similar practical things done from space. The United States has now flown Landsat 1, 2, and 3 (previously known as ERTS) and also Seasat and HCMM to conduct such experiments.

The Soviet Union has expressed a similar interest. Recent Soyuz flights and the Salyut stations were announced as having explored data-gathering techniques for Earth resources purposes. During 1977, two short-life recoverable Kosmos flights and in 1978 two more were specifically identified as doing Earth-resources work. In 1979, ten such flights were identified, plus two ocean resources flights. In 1980, there were seven more such flights identified, plus an ocean resources payload. Seven Soviet earth resources, and possibly two ocean resource flights were made in 1981. An Indian earth resources satellite was also launched by the Soviets in 1981. The identified Earth resources flights are indistinguishable from military observation recoverable flights aside from the labeling.

The Soviets are also experimenting with advanced sensors for earth resources sensing in the Meteor 2 series of flights.

F. SUMMARY TABLE OF SPACE MISSION BY CATEGORY

The table which follows is somewhat arbitrary in classification, but attempts to place in broad mission category each payload launched since 1957 by the United States and the Soviet Union. Insofar as possible, categories between the two countries have been matched, but there remain minor differences. For example, the United States has not used the orbital launch platform concept on as large a scale; the Soviet Union has not designed special payloads to circle the Sun for measuring the interplanetary medium.

The table gives at least an indication as to the amount of activity by each country in major areas of space applications, such as weather, communications, and navigation. The United States has a large category of military missions not classified as to specific intent, beyond their developmental and support role. These have been grouped arbitrarily by orbital characteristics for approximate comparison purposes. Their groupings by possibly recoverable or non-recoverable categories may suggest parallels in mission, but public evidence is not conclusive.

TABLE 7 -- Summary of U.S. and Soviet Space Payloads by Mission
1957-1981

	United States	Soviet Union
Orbital launch platforms		226
Earth orbital science	175	178
General engineering tests	28	2
Launch vehicle tests	11	16
Applications		
Communications	160	117
Weather	80	53
Geodesy	19	21
Earth resources	5	11
Man and biology related		
Earth orbit man-related	13	61
Earth orbit manned	22	54
Lunar man-related	17	8
Lunar manned	20	
Deep space (other than man-related)		
Moon	25	34
Mercury	1	
Venus	8	29
Mars	9	16
Outer planets	4	
Interplanetary space	8	
TOTAL "CIVIL"	605	826
Military observation		
Low orbit recoverable (photo?0	233	529
Low orbit non-recoverable (elint?)	81	70
Minor military (calibration?)	43	123
High orbit (early warning?)	41	25
Ocean surveillance	12	32
Navigation	41	62
Tactical and store/dump communications		273
Weapons-related		
Fractional orbit bombardment		18
Targets for anti-satellites		17
Anti-satellite interceptors		19
TOTAL "MILITARY"	451	1,168
GRAND TOTAL	1,056	1,994

Mission assignments are arbitrary to a degree, and are subject to revision each year as more information becomes availab.e Qualifying footnotes to be comprehensive would fill many pages. For example, many applications satellites may have either civil or military users; among the military photographic recoverable flights are 24 that have been labeled as performing Earth resources missions for the U.S.S.R. Perhaps arbitrary assignments by category which may be either too high or too low sufficiently cancel out simplifications so that the totals for military and civil are generally indicative of divisions.

CHAPTER SEVEN: LUNAR AND PLANETARY

The Soviet Union has made an effort comparable to that of the United States in number of flights committed to lunar and planetary work, but so far, has not gained as good results. However, only 3.8 percent of Soviet successful flights have been in the "escape mission" category, compared with the 7.6 percent in the United States, mostly because of the continued expansion of the Soviet Earth orbital applications effort.

A. SURVEYOR AND LUNAR ORBITER VS. LUNA 4-14

In 1963, both the United States and the Soviet Union planned to land survivable payloads on the Moon. The U.S. program was called Surveyor, and although it did not fly until 1966, it was a very great success. The several Surveyors which landed intact returned close to 100,000 pictures of their immediate surroundings and dug holes in the surface by remote control and determined the chemical composition of the lunar soil by an indirect means.

By contrast, the Soviet Union started landing attempts in 1963, but later admitted that Luna 4, 5, 6, 7, and 8 failed to achieve a survivable landing. Additionally, one unnamed flight and Kosmos 60 were lunar failures which did not leave Earth orbit. When Luna 9 in 1966 finally made it to the surface, the landing was not as gentle as a Surveyor landing, and the television camera returned only 27 pictures of the surroundings. Luna 13 additionally did impact testing of the soil with an extendable arm.

This comparison shows how difficult it can be to draw a balance sheet between two programs. U.S. Surveyors were more impressive than the Soviet Luna ships. But along with this, one must also note that Luna 9 landed a working camera before the first Surveyor, and the 27 Soviet pictures essentially answered the basic questions about the surface of the Moon, even though these did not compare in number with the thousands of pictures from Surveyor.

In the case of orbiters there were also different comparisons to draw, but the total usefulness of the U.S. Lunar Orbiters seems hard to contest. The Soviet Luna 10 reached a successful orbit before the first U.S. Lunar Orbiter, and its indirect measure told the Russians something of the probable composition of the lunar surface and also about gravity anomalies. Luna 12 in 1966 finally returned a few pictures to supplement earlier Soviet pictures taken of the far side by Luna 3 in 1959 and Zond 3 in 1965. But in no real sense did the few score Soviet pictures from these flights come anywhere near the clarity, detail, and variety of the five sets of Lunar Orbiter views, each of which returned about 200 double frames (simultaneous views through narrow angle and wide angle lenses). The subsequent Luna 14 seems only to have been an extension of the work of the non-picture-taking Luna 10. (Additional Soviet lunar orbiters are discussed in section D.)

Zond 5 and 6, the 1968 unmanned precursors to projected later manned flights, did better in picture quality because they returned actual photographs to Earth in the same manner as was done shortly thereafter by Apollo 8. Zond 7 in 1969 and Zond 8 in 1970 performed tasks similar to those of the two preceding Zonds.

B. SOVIET LUNAR SAMPLE RETURN FLIGHTS

In July 1969, the Russians sent Luna 15 to the Moon (using a large D class launch vehicle) at a time overlapping with the flight of Apollo 11. Its mission cannot be determined because it crashed during a soft landing attempt.

In 1970, Luna 16 maneuvered into lunar orbit, then landed, and by remote control bored a sample core 35 centimeters in length, weighing 101 grams, which was sealed in a container and rocketed back to Earth for recovery in the Soviet Union. Although the sample was small, it provided useful analytical material for a special quarantine laboratory similar to the Houston, Texas facility.

Luna 18, launched in 1971 on a similar mission, made a bad landing and was destroyed. Luna 20 in 1972 repeated the success of Luna 16, returning a sample from highlands, contrasted with the mare sample of its predecessor. Luna 23 in 1974 survived its landing, but its drill was damaged in landing, and after a few days the experiment was shut down without a sample return.

Luna 24 in 1976 was the most successful, being able to drill to a depth of 2 meters and returning all this sample core to Earth.

A total of 330 grams of lunar material was returned by the Soviet Luna spacecraft, compared with 380 kilograms returned by the U.S. Apollo crews.

C. SOVIET LUNAR SURFACE ROVING VEHICLES

Luna 17 was the first successful landing of a Lunokhod roving vehicle weighing 756 kilograms. After landing on November 17, 1970, it continued to function until October 4, 1971, traveling 10,540 meters over the surface, and returning 20,000 television views, 200 detailed panoramas, 500 soil-property tests, 25 soil chemical analyses, and a number of astronomical observations with its X-ray telescope.

Luna 21 in 1973 landed Lunokhod 2 (840 kilograms), which operated for three months, but traveled 37,000 meters in that time, and returned proportionately more data and pictures also, despite its shorter life than Lunokhod 1.

D. SOVIET LUNAR ORBITERS

The same D class launch vehicles used for the sample return and surface roamer missions was also used to place heavy payloads in lunar orbit in 1971 and 1974. Luna 19 was sent to the Moon in 1971, and remained under active control for about a year, gathering a wide variety of synoptic data and some pictures. Lune 22 in 1974 was a similar mission, remaining under active control for about a year and a half. During many maneuvers it was able to take high resolution pictures at some close approaches to the Moon.

E. U.S. PLANETARY MISSIONS

The U.S. Mariner program of three-axis stabilized probes has launched ten vehicles, of which six returned planetary data. Mariner 2 and 5 brought

back indirect readings from Venus. Mariner 4, 6, 7, and 9 brought back increasingly good pictures of the surface features of Mars. Mariner 10 not only returned good pictures of the cloud patterns of Venus, but made three photographic passes by Mercury with good results.

The Pioneer series of spin-stabilized spacecraft has seen 18 launch attempts, of which 12 were at least partially successful. Pioneer 1 and 3 did not reach their intended trajectories to the Moon, but did send back data about Earth's atmosphere. Pioneer 4 successfully returned data as it flew past the Moon and entered heliocentric orbit. Pioneers 5 through 9 were designed to study the area of space between the Earth and Sun, and did so successfully. Pioneers 6, 7, 8, and 9, launched between 1965 and 1968, were still returning data at the end of 1981.

Pioneers 10 and 11 were the first planetary probes of the Pioneer series, and were launched to investigate Jupiter, Saturn, and the interplanetary medium. Both probes sent back pictures of Jupiter in 1973 and 1974 respectively; Pioneer 10 then was placed on a trajectory out of the solar system, while Pioneer 11 continued on to a successful encounter with Saturn in 1979. Pioneer 10 continues to return data on its way out of the solar system, and by the end of 1981, was more than 3,750,000,000 kilometers (25 astronomical units) from Earth.

Pioneer Venus 1 and 2 were launched in 1978 and reached Venus in December of that year. Pioneer Venus 1 is an orbiter, which at the end of 1981 was continuing to return data about Venus. Pioneer Venus 2 consisted of 5 separate probes, all of which descended through the Venusian atmosphere

to make in situ measurements of its characteristics. Although they were not designed to withstand landings on the planet, two of the probes did survive and transmitted data for as long as 67 minutes after impact.

Viking 1 and 2, launched in 1975, each were orbiter/lander combinations. The orbiters mapped the surface of Mars and collected clear views of Deimos and Phobos. The landers sent back color pictures from the surface, and their on-board laboratories conducted a search for life with puzzling, inconclusive findings. At the end of 1981, one lander was still operational.

Voyager 1 and 2 were launched in 1977 toward Jupiter and the outer planets. During 1979 they returned astonishing color pictures not only of Jupiter but also of its larger moons, each unique and unexpected in appearance. Voyager 1 returned equally exciting pictures of Saturn, Titan, and other moons during 1980, and Voyager 2 returned additional data on Saturn in 1981. Voyager 2 is now enroute to Uranus with closest approach expected in 1986.

F. SOVIET PLANETARY MISSIONS

The commitment of payloads to planetary missions by the Russians has been much heavier than by the Americans, but with mixed results. Two Mars attempts as early as 1960 failed to reach even Earth orbit. In 1961, there were two Venus attempts, with Venera 1 reaching the vicinity of the planet in non-operating condition. In 1962, there were three more Venus attempts and three Mars attempts, with five of these payloads stranded Earth orbit, and Mars 1 in non-operating condition when it reached the vicinity of that planet. Zond 1, Venera 2, and Venera 3 were not in operating condition when

they reached Venus. Zond 2 made a close fly-by of Mars in non-operating condition. Zond 3 was expended as a test flight taking pictures of the far side of the Moon and rebroadcasting these to Earth as it traveled as far as the orbit of Mars.

Results improved for the Russians when Venera 4, 5, 6, 7 and 8 all functioned to return direct readings within the atmosphere of Venus. Of these Venera 7 survived a Venus landing and broadcast for 23 minutes on the surface. Venera 8 had similar success, plus doing soil analyses.

As in the lunar program, the Russians shifted from use of the A class launch vehicle to the D class so that Venera 9 and 10 in 1975 accomplished the nearest Venus equivalent of American Viking missions to Mars. The orbital vehicles returned pictures and other data for many months in orbit. The landers operated about an hour on the surface, and their cameras returned good pictures of the farside surface, relayed via the orbiters. This was a remarkable feat, considering the 485°C temperature.

Venera 11 and 12 were sent to Venus in 1978, at approximately the same time as the U.S. Pioneer-Venus probes. No photographs were returned by these spacecrafts, and Soviet scientists have told their U.S. counterparts that the imaging systems failed. Data was returned on other aspects of the Venusian atmosphere and surface. In late 1981, Venera 13 and 14 were launched. They are thought to be similar to Venera 9, 10, 11, and 12.

The D class vehicle was also used for the launchings of Mars 2 through 7. Mars 3 was the first to make a survivable landing with television, but signals ceased before the first complete picture was received on Earth. Mars 4 and 5

were intended as orbiters working with Mars 6 and 7 landers. Of these four only Mars 5 attained an orbit and Mars 6 a landing. Mars 6 returned direct readings within the atmosphere but signals ceased at the surface.

Six other Venus related flights were stranded in Earth orbit over the years, in addition to those already mentioned. One other Mars flight ended in Earth orbit in addition to those mentioned earlier. There have also been press reports of additional Mars flight attempts which did not even reach Earth orbit, which reports are consistent with the failure of flights to appear to match the Russians' own predictions of their plans.

Had the heavy Mars vehicles of the U.S.S.R. been successful, many of the firsts of the Viking programs would have been Soviet prizes. Soviet orbiters in general put greater emphasis on a wide range of synoptic data readings, with color pictures less prominent than in the U.S. operations. The D class Soviet launch vehicle has demonstrated an ability to carry payloads up to 4,650 kilograms to Mars and 5,033 kilograms to Venus. The Venus landers weigh 1,560 kilograms each. These weights compare U.S. Vikings at 3,400 kilograms and Viking landers at 1,090 kilograms each.

G. SUMMARY TABLES ON LUNAR AND PLANETARY FLIGHTS

The first table to follow summarizes the known lunar attempts of the two countries. The second table does the same for known planetary attempts. In both cases, the Soviet record may understate the realities because of their penchant for secrecy in hiding failures.

TABLE 8 -- Summary of Lunar Distance Flight Attempts

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
1958						
Aug. 17	Pioneer 0	US	38	38	Orbit Moon	Fail--exploded 16 km up.
Oct. 11	Pioneer 1	do	38	76	do	Fail--climbed 113,830 km, fell back over South Pacific.
Nov. 8	Pioneer 2	do	39	115	do	Fail--climbed 1,550 km, fell near Africa.
Dec. 6	Pioneer 3	do	6	121	Fly by Moon	Fail--climbed 102,320 km, fell back over Africa.
1959						
Jan. 2	Luna 1	USSR	361	361	Strike Moon	Partial--missed Moon by 5-6,000 km, entered solar orbit.
Mar. 3	Pioneer 4	US	6	127	Fly by Moon	Success--passed Moon at 60,050 km, entering solar orbit.
Sept. 12	Luna 2	USSR	390	751	Strike Moon	Success--struck 335 km.
Sept. 24	Pioneer P-1	US	170	297	Orbit Moon	Fail--exploded in static test before launch.
Oct. 4	Luna 3	USSR	435	1,186	Photo far side	Succeed--returned pictures of 70 percent of far side of Moon.
Nov. 26	Pioneer P-3	US	169	466	Orbit Moon	Fail--shroud tore away in launch, payload impacted near Africa.
1960						
Sept. 25	Pioneer P-30	do	176	642	do	Fail--impacted in Africa.
Dec. 15	Pioneer P-31	do	176	818	do	Fail--climbed 13 km and exploded.
1961						
Aug. 23	Ranger 1	do	306	1,124	Vehicle test	Fail--intended to climb to 1,102,850 km, but stayed in low Earth orbit.
Nov. 18	Ranger 2	do	306	1,430	do	Fail--intended to climb to 1,102,850 km, but stayed in low Earth orbit.
1962						
Jan. 26	Ranger 3	do	330	1,760	TV, hard land	Partial--missed Moon by 36,808 km, no TV pictures or landed instruments.

TABLE 8 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Apr. 23	Ranger 4	US	331	2,091	TV, hard land	Partial--timer failed, fell on far side of Moon, no pictures.
Oct. 18	Ranger 5	do	342	2,433	do	Partial--power failure, so missed Moon by 725 km, entered solar orbit.
1963						
Jan. 30	Unannounced	USSR	1,400?	2,586	Moon soft land	Failed--Earth orbit only.
Apr. 2	Luna 4	do	1,422	4,008	do	Partial--missed Moon by 8,500 km, barycentric or solar orbit.
1964						
Jan. 30	Ranger 6	US	365	2,798	TV before strike	Partial--on target, but no pictures taken.
Jul. 28	Ranger 7	do	366	3,164	do	Success--returned 4,308 pictures of Moon to impact.
Dec. 11	Centaur 2	do	952	4,116	Vehicle test	Fail--did not restart and soon fell in Australia.
1965						
Feb. 17	Ranger 8	do	367	4,483	TV before strike	Fail--returned 7,137 pictures of Moon to impact.
Mar. 2	Centaur AC 5	do	635	5,118	Vehicle test	Fail--exploded at pad.
Mar. 12	Kosmos 60	USSR	1,470	5,478	Moon soft land	Fail--Earth orbit only.
Mar. 21	Ranger 9	US	366	4,484	TV before strike	Success--returned 5,814 pictures of Moon to impact.
May 9	Luna 5	USSR	1,476	6,954	Moon soft land	Partial--missed Moon by 160,000 km, entered solar or barycentric orbit.

TABLE 8 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
June 8	Luna 6	do	1,442	8,396	do	Partial--missed Moon by 160,000 km, entered solar or barycentric orbit.
Jul. 18	Zond 3	US	890?	9,286	Photo far side	Success--returned 25 pictures, entered solar orbit.
Aug. 11	Centaur 3	US	952	6,436	Vehicle test	Success--reached 820,824 km out with Surveyor dynamic model, in barycentric orbit.
Oct. 4	Luna 7	USSR	1,506	10,792	Moon soft land	Partial--retrofired early, fell on Moon.
Dec. 3	Luna 8	do	1,552	12,344	do	Partial--retrofired late, fell on Moon.
1966 Jan. 31	Luna 9	do	1,583	13,927	do	Success--returned 27 pictures from lunar surface.
Feb. 26	Apollo-Saturn 201	US	15,331	27,767	Vehicle test	Success--flew sub-orbitally to land in the Pacific.
Mar. 1	Kosmos 111	USSR	1,600?	15,527	Moon orbit	Fail--Earth orbit only.
Mar. 31	Luna 10	do	1,600	17,127	do	Success--returned physical measurements from lunar orbit.
Apr. 8	Centaur 4	US	771	28,538	Vehicle test	Fail--low Earth orbit only.
May 30	Surveyor 1	do	995	29,533	Moon soft land	Success--returned 11,237 pictures from lunar surface.
Jul. 1	Explorer 33	do	93	29,626	Moon orbit	Partial--failed to approach Moon in barycentric orbit.
Jul. 5	Apollo-Saturn 203	do	26,535	56,161	Vehicle test	Success--simulated in Earth orbit a Saturn V flight.

TABLE 8 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Aug. 10	Lunar Orbiter 1	do	387	56,548	Moon orbit	Success--returned 414 pictures of potential landing sites on Moon.
Aug. 24	Luna 11	USSR	1,604?	18,767	do	Success--but failed to return pictures from lunar orbit.
Aug. 25	Apollo-Saturn 202	US	20,275	76,823	Vehicle test	Success--simulated reentry in sub-orbital flight.
Sep. 20	Surveyor 2	do	1,000	77,823	Moon soft land	Partial--stabilization failed, struck Moon.
Oct. 22	Luna 12	USSR	1,625?	20,392	Vehicle test	Success--returned pictures of Moon.
Oct. 26	Centaur 2	US	726	78,549	Vehicle test	Success--mass model of Surveyor carried to 465,032 km.
Nov. 6	Lunar Orbiter 2	do	390	78,939	Moon orbit	Success--returned 422 pictures of Apollo sites, far side.
Dec. 21	Luna 13	USSR	1,595?	21,987	Moon soft land	Success--returned pictures and soil density measures.
1967						
Jan. 27	Apollo-Saturn 204	US	20,412	99,351	Capsule test	Fail--burned on pad in exercise.
Feb. 5	Lunar Orbiter 3	US	385	99,736	Moon orbit	Success--returned 307 pictures of Apollo sites.
Apr. 17	Surveyor 3	do	1,035	100,771	Moon soft land	Success--returned 6,315 pictures, dug soil with shovel.
May 4	Lunar Orbiter 4	do	390	101,161	Moon orbit	Success--returned 326 pictures of large areas of the Moon.

TABLE 8 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Jul. 14	Surveyor 4	do	1,039	102,200	Moon soft land	Partial--signals ceased at touchdown on Moon.
Jul. 19	Explorer 35	do	104	102,304	Moon orbit	Success--returned data from lunar orbit.
Aug. 1	Lunar Orbiter 5	do	390	102,694	do	Success--returned 424 pictures including much of far side.
Sep. 8	Surveyor 5	do	1,005	103,699	Moon soft land	Success--returned 18,006 pictures, chemical analysis of soil.
Nov. 7	Surveyor 6	do	1,008	104,7[illegible]	do	Success--returned 30,065 pictures, chemical and mechanical soil study.
Nov. 9	Apollo 4	do	42,506	147,213	Vehicle test	Success--simulated full lunar return reentry in Earth orbit.
1968 Jan. 7	Surveyor 7	do	1,040	148,253	Moon soft land	Success--returned 21,274 pictures, chemical analysis of soil from trench it dug.
Jan. 22	Apollo 5	do	14,379	162,632	Vehicle test	Success--tested lunar module in Earth orbit.
Mar. 2	Zond 4	USSR	5,800?	27,787	do	Partial--flew to lunar distance but recovery in doubt.
Apr. 4	Apollo 6	US	42,577	205,209	do	Partial--did not go to lunar distance but recovered payload.
Apr. 7	Luna 14	USSR	1,615?	29,402	Moon orbit	Success--returned data on lunar mass distribution.

TABLE 8 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Sep. 14	Zond 5	USSR	5,800?	35,202	Circumlunar	Success--ballistic reentry with biological subjects and pictures.
Oct. 11	Apollo 7	US	20,577	225,786	Manned test	Success--flew in Earth orbit.
Nov. 10	Zond 6	USSR	5,800?	41,002	Circumlunar	Success--lifting reentry with biological specimens and pictures.
Dec. 21	Apollo 8	US	43,654	269,440	Moon orbit	Success--men in lunar orbit and recovered.
1969						
Mar. 3	Apollo 9	do	47,167	316,607	Manned test	Success--tested lunar module rendezvous, crew recovered.
May 18	Apollo 10	do	48,638	365,245	Moon orbit	Success--tested lunar module rendezvous, at Moon, crew recovered.
Jul. 13	Luna 15	USSR	5,800?	46,802	Moon soft land	Partial--lunar orbit success, but landing failed.
Jul. 16	Apollo 11	US	49,698	414,943	do	Success--first manned landing on Moon and return.
Aug. 7	Zond 7	USSR	5,800?	52,602	Circumlunar	Success--lifting reentry of photographs.
Sep. 23	Kosmos 300	do	5,800?	58,402	Moon soft land	Fail--Earth orbit only.
Oct. 22	Kosmos 305	do	5,800?	64,202	do	Fail--Earth orbit only.
Nov. 14	Apollo 12	US	49,804	464,747	do	Success--manned lunar landing and return with part of Surveyor 3.
1970						
Apr. 11	Apollo 13	do	49,990	514,737	do	Partial--explosion in service module limited flight to circumlunar; crew saved.

TABLE 8 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Sep. 12	Luna 16	USSR	5,800?	70,002	do	Success--made automated sample collection returned it to Earth.
Oct. 20	Zond 8	do	5,800?	75,802	Circumlunar	Success--ballistic reentry with photographs.
Nov. 10	Luna 17	USSR	5,800?	81,602	Moon soft land	Success--landed automated roving vehicle for long term exploration.
1971 Jan. 31	Apollo 14	US	46,346	561,083	do	Success--manned lunar landing and return.
July 26	Apollo 15	do	52,759	613,842	do	Success--manned lunar landing, roving vehicle, safe return.
Sep. 2	Luna 18	USSR	5,800?	87,402	do	Partial--lunar orbit success, but crashed on landing.
Sep. 28	Luna 19	do	5,800?	93,202	Moon orbit	Success--returned photographs and other data.
1972 Feb. 14	Luna 20	do	5,800?	99,002	Moon soft landing	Success--made automated sample collection, returned it to Earth.
Apr. 16	Apollo 16	US	48,606	662,448	do	Success--manned lunar landing roving vehicle, safe return.
Dec. 7	Apollo 17	do	46,825	709,273	do	Success--manned lunar landing, roving vehicle, safe return.
1973 Jan. 8	Luna 21	USSR	5,800?	104, 802	do	Success--landed automated roving vehicle for long term exploration.

TABLE 8 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Jun. 10	Explorer 49	US	328	709,601	Moon orbit	Success--radio astronomy from far side of Moon.
1974						
May 29	Luna 22	USSR	5,800?	110,602	do	Success--returned pictures and data.
Oct. 28	Luna 23	do	5,800?	116,402	Moon soft land	Partial--landed safely, but drill damaged so no sample returned to Earth.
1976						
Aug. 9	Luna 24	do	5,800?	122,202	do	Success--made automated sample collection, returned to Earth.

NOTES

1. The table includes all known attempts to send payloads to the Moon or to distances from Earth equal to the distance of the Moon from Earth, together with test flights in Earth orbit of lunar-associated hardware. It cannot include Soviet flight failures which did not reach Earth orbit because these are not in the public domain. Hence, the cumulative weight of Soviet payloads almost certainly understates reality.

2. Weights listed are in kilograms, with a second column showing a running total of kilograms for all flights to data of the same national origin.

3. In a very few instances, the mission has been assigned by inference, in terms of the context of the time in which it took place.

4. The test of success or failure is somewhat arbitrary. Any flight staying in relatively low Earth orbit as well as not achieving Earth orbit is counted as a failure. Flights which at least approached the Moon, although not achieving the estimated goal received the rating of partial success.

5. The Soviet label Luna was applied after the fact to the first flights which at the the were simply called Cosmic Rockets, with the third one called an Automatic Interplanetary Station (AIS 1). Luna 1 was also called Mechta (Dream).

SOURCES: Soviet data are from Soviet TASS bulletins for the most part, supplemented by inferential judgments that some Earth orbital flights were almost certainly lunar attempts which failed, based upon the timing of the launch, the nature of the debris in Earth orbit, the launch vehicle used, and the orbital path chosen. U.S. data are based mostly on NASA press releases, although the first lunar attempt was sponsored and reported on by the Advanced Research Projects Agency (ARPA) of the Department of Defense before the creation of NASA. Estimated weights of Luna 11, 12, 13 and 14 by D.R. Woods. Weights of Luna 15 on, and Zond 4-8 were estimated by the Royal Aircraft Establishment.

TABLE 9 -- Summary of Planetary Distance Flight Attempts

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
1960						
Mar. 11	Pioneer 5	US	43	43	Interplanetary toward Sun	Success--returned data from 36.2 million kilometers.
Oct. 10	Unacknowledged	USSR	640?	640?	Mars	Fail--did not reach Earth orbit.
Oct. 14	do	do	640?	1,280	do	Fail--did not reach Earth orbit.
1961						
Feb. 4	Tyazheliy Sputnik 4	do	640?	1,920	Venus	Fail--Earth orbit only.
Feb. 14	Venera 1	do	644	2,564	do	Partial--communications failed; passed Venus at 100,000 km.
1962						
Jul. 22	Mariner 1	US	202	245	Venus flyby	Fail--destroyed at 160 km altitude.
Aug. 25	Unacknowledged	USSR	890?	3,454	Venus	Fail--Earth orbit only.
Aug. 27	Mariner 2	US	203	408	Venus flyby	Success--passed Venus at 34,853 km.
Sep. 1	Unacknowledged	USSR	890?	4,344	Venus	Fail--Earth orbit only.
Sep. 12	Unacknowledged	do	890?	5,234	do	Fail--Earth orbit only.
Oct. 24	Unacknowledged	do	890?	6,124	Mars	Fail--Earth orbit only.
Nov. 1	Mars 1	do	894	7,018	do	Partial--communications failed, passed Mars at 191,000 km.
Nov. 4	Unacknowledged	do	890?	7,908	do	Fail--Earth orbit only.
Nov. 11	Kosmos 21	do	890?	8,798	Venus test	Fail--Earth orbit only.
1964						
Mar. 27	Kosmos 27	do	890?	9,688	Venus	Fail--Earth orbit only.
Apr. 2	Zond 1	do	890?	10,578	do	Partial--communications failed, passed Venus at 100,000 km.
Nov. 5	Mariner 3	US	261	669	Mars flyby	Fail--shroud did not separate, thrown into wrong orbit.
Nov. 28	Mariner 4	do	261	930	do	Success--returned 22 pictures.
Nov. 30	Zond 2	USSR	890?	11,468	Mars	Partial--communications failed, passed Mars at 1,500 km.

TABLE 9 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
1965						
Jul. 18	Zond 3	USSR	890?	12,358	Mars test	Success--returned 25 pictures of Moon far side, retransmitted from increasing distances.
Nov. 12	Venera 2	do	963	13,321	Venus flyby	Partial--communications failed, passed Venus at 24,000 km.
Nov. 16	Venera 3	do	960	14,281	Venus land	Partial--communications failed, struck Venus 450 km from visible center.
Nov. 23	Kosmos 96	do	960?	15,241	Venus	Fail--Earth orbit only.
Dec. 16	Pioneer 6	US	61	991	Interplanetary toward Sun	Success--returned data.
1966						
Aug. 17	Pioneer 7	do	61	1,052	Interplanetary away from Sun	Success--returned data.
1967						
Jun. 12	Venera 4	USSR	1,106	16,347	Venus land	Success--returned direct readings of atmosphere to 25 km altitude.
Jun. 14	Mariner 5	US	245	1,297	Venus flyby	Success-returned data, passed Venus at 4,094 km.
Jun. 17	Kosmos 167	USSR	1,100?	17,447	Venus	Fail--Earth orbit only.
Dec. 13	Pioneer 8	US	66	1,363	Interplanetary away from Sun	Success--returned data.
1968						
Nov. 8	Pioneer 9	do	67	1,430	Interplanetary toward Sun	Success--returned data.
1969						
Jan. 5	Venera 5	USSR	1,130	18,577	Venus land	Success--returned direct readings of atmosphere to near surface.

TABLE 9 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
Jan. 10	Venera 6	USSR	1,130	19,707	Venus land	Success--returned direct readings of atmosphere to near surface.
Feb. 25	Mariner 6	US	380	1,810	Mars flyby	Success--returned 24 pictures and other data.
Mar. 27	Mariner 7	do	380	2,190	do	Success--returned 31 pictures and other data.
Aug. 27	Pioneer E	do	66	2,256	Interplanetary at Earth orbit	Fail--destroyed by range safety.
1970						
Aug. 17	Venera 7	USSR	1,180	20,887	Venus soft land	Success--sent back data from atmosphere and surface of Venus.
Aug. 22	Kosmos 359	do	1,180	22,067	do	Fail--Earth orbit only.
1971						
May 8	Mariner 8	US	1,029	3,285	Mars orbit	Fail--fell in Atlantic Ocean.
May 10	Kosmos 419	USSR	4,650?	26,717	Mars soft land	Fail--Earth orbit only.
May 19	Mars 2	do	4,650	31,367	do	Partial--returned data from orbiter, but lander destroyed.
May 28	Mars 3	do	4,650	36,017	do	Success--returned orbital data and survived landing.
May 30	Mariner 9	US	1,030	4,315	Mars orbit	Success--returned 6,786 pictures of Mars.
1972						
Mar. 3	Pioneer 10	do	258	4,573	Jupiter flyby	Success--returned pictures and other data.
Mar. 27	Venera 8	USSR	1,180?	37,197	Venus soft land	Success--atmospheric data and soil analysis returned.
Mar. 31	Kosmos 482	do	1,180?	38,377	do	Fail--Earth orbit only.

TABLE 9 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
1973						
Apr. 6	Pioneer 11	US	259	4,832	Jupiter, Saturn flyby	Success--returned Jupiter and Saturn pictures and data.
Jul. 21	Mars 4	USSR	4,150?	42,527	Mars orbit	Partial--returned data and in flyby, did not enter orbit.
Jul. 25	Mars 5	USSR	4,150?	46,677	Mars orbit	Success--returned data and pictures.
Aug. 5	Mars 6	do	4,150?	50,827	Mars soft land	Partial--returned data from flyby, but lander signals ceased.
Aug. 9	Mars 7	do	4,150?	54,977	do	Partial--returned data from flyby, but lander missed by 1,300 km.
Nov. 3	Mariner 10	US	504	5,336	Venus, Mercury flyby	Success--returned pictures from Venus and three times pictures from Mercury.
1974						
Dec. 10	Helios 1	German Fed. Rep./US	370	5,706	Sun approach	Success--returned data.
1975						
Jun. 8	Venera 9	USSR	4,936	59,913	Venus soft landing	Success--returned pictures and other data.
Jun. 14	Venera 10	do	5,033	64,946	do	Success--returned pictures and other data.
Aug. 20	Viking 1	US	3,400	9,106	Mars soft landing	Success--returned pictures and other data.
Sep. 9	Viking 2	do	3,400	12,506	do	Success--returned pictures and other data.
1976						
Jan. 15	Helios 2	German Fed. Rep./US	376	12,882	Sun approach	Success--returned data.

TABLE 9 (continued)

Launch date	Spacecraft name	Nationality	Weight (kg)	Cumulative national weight	Mission	Results
1977						
Aug. 20	Voyager 2	US	700	13,582	Jupiter, Saturn, Uranus flybys	Success--returned pictures and data from Jupiter.
Sep. 5	Voyager 1	do	700	14,282	Jupiter, Saturn flybys	Success--returned pictures and data from Jupiter and Saturn.
1978						
May 20	Pioneer Venus 1	do	549	14,831	Venus orbit	Success--returned data and pictures.
Aug. 8	Pioneer Venus 2	do	904	15,735	Venus probe	Success--five vehicles returned direct data from atmosphere.
Sep. 9	Venera 11	USSR	3,940?	66,586	Venus soft land	Success--returned data from surface.
Sep. 14	Venera 12	do	3,940?	72,826	do	Success--returned data from surface.
1981						
Oct. 20	Venera 13	do	3,940?	76,766	do	Expected to land on March 1, 1982.
Nov. 4	Venera 14	do	3,940?	80,706	do	Expected to land on March 5, 1982.

NOTES

1. The table includes all known attempts to send payloads to the planets or into solar orbit, not including those intended to go to the Moon which only incidentally may have escaped barycentric orbit to enter heliocentric orbit. It cannot include additional Soviet flight failures which did not reach Earth orbit, when not in the public domain. The only year in which there had been persistent reports of Soviet intentions to launch planetary flights for which there is no public record of failures is 1969. This could mean that Mars flights using the D-1-e vehicle began in that year, but failed to reach Earth orbit.

2. Weights listed are in kilograms, with a second column showing a running total of kilograms for all flights to date of the same national origin.

3. In a few instances, the mission has been assigned by inference, in terms of the context of the time in which it took place. Some of the Soviet flights to the planets may have been orbiters or landers, but no attempt has been made to guess the mission other than that of the planet name.

4. The test of success or failure is somewhat arbitrary. Any flight staying in relatively low Earth orbit as well as those not achieving Earth orbit are counted as failures. Flights at least approaching interplanetary distances although not achieving their estimated goal received the rating of partial success.

SOURCES: Soviet data are from Soviet TASS bulletins for the most part, supplemented by inferential judgments that some Earth orbital flights were almost certainly planetary attempts which failed, based on the timing of the launch, the nature of the debris in Earth orbit, the launch vehicle used, and the orbital path chosen. U.S. data are based mostly on NASA press releases. Weight estimates for the more recent Mars and Venus flights by the Russians have been varied from the weight of Mars 2 and 3 at the suggestion of O.E. Woods and C.P. Vick, to reflect approximate energy requirement effects on payloads.

CHAPTER EIGHT: FUTURE DIRECTIONS FOR THE SPACE PROGRAMS

Attempting to predict the future of the space program is a difficult assignment as it depends upon political decisions as much as on technical capabilities. At least, there are more engineering possibilities than there are financial resources likely to be made available to pursue them. The issue of future goals has been with the United States for several years, particularly after the accomplishment of the dominating Apollo mission.

Estimating what the Soviet Union will elect to do in space may be even harder for a Western observer because of Soviet restrictions on freedom of information. The United States abounds in paper plans, but until the President and the Congress agree on funding, U.S. plans stay on paper, and there is no formal commitment to go ahead. In the Soviet case, they have stated at several levels of authority, including the highest, more positively their long run goals, although without a real, public timetable. They, too, undoubtedly have to face hard budget choices before actual hardware work can begin.

The announced Soviet goal is a comprehensive exploitation of space technology including the exploration and settlement (where practical) of the planets, along the way exploring the Moon in greater detail, and using Earth orbital stations for a host of practical purposes. The immediate purpose of this paper is again to pose questions about the choices immediately before each country, and to estimate how well they should be able to respond.

A. IMPLICATIONS OF THE U.S. SPACE SHUTTLE AND POSSIBLE SOVIET DEVELOPMENT OF A REUSABLE VEHICLE

The U.S. space shuttle was designed to be the national space launching system for all purposes--military, civil, and commercial. Because it is a reusable system, it is expected to reduce the costs associated with launches, although a firm pricing policy for the shuttle past the year 1985 (when the shuttle will be fully operational) has not been established yet.

Uses of the shuttle have not been defined yet, either, other than for the routine launching of free-flying satellites for purposes such as communications, meteorology, science, and military reconnaissance. As noted elsewhere in this report, the 1969 space program plan for the United States which included the space shuttle also included a space station which would be serviced by the shuttle. Although the United States abandoned plans for a space station because of budgetary constraints within NASA, these plans are now being reconsidered (see section below on manned space stations).

Some of the possible uses of space which have been envisioned in the shuttle era include materials processing in space, and constructing large space structures which could incorporate the functions of several different types of satellites which are flown individually at the present time (such as communications and meteorological observations). There are also potential military uses of the space shuttle, including reconnaissance, although these plans have not been openly discussed.

The existing space shuttle is seen only as the first of an evolutionary series of manned and unmanned reuseable space vehicles. One concept under

study at the present time is called SRB-X which would be an unmanned derivative of the shuttle for lifting very heavy payloads into orbit.

The Soviet Union has shown an equal awareness of the potential of reusable vehicles, and various Soviet space officials have stated their own convictions that such development is essential. But in keeping with Soviet practice, internal debates, or even decisions without debate, about new technology are not exposed in any public forum, so the current status of the Soviet effort, if any, in this regard is not known. Considering the Soviet effort to maintain a position of leadership in space, and the continued high level of Soviet flight activity (over five times that of the United States), they have even more compelling reasons to develop a reusable shuttle as a cost saving device. It is hard to imagine their attainment of announced goals, to be discussed presently, without use of a shuttle.

The U.S. trade press claimed that in 1978 a Soviet reusable orbiter has undergone drop test from a Tu-95 bomber. Unexplained Soviet reentry tests in 1977, 1978, and 1979 could conceivably relate to a Soviet shuttle. During 1981, when the U.S. achieved success with its shuttle, statements by Soviet space personalities, such as the cosmonauts, referred to the fact that a Soviet shuttle would not be economical at this time. These statements do not preclude Soviet development of a reusable vehicle, but suggest it will not be ready for some time.

B. PLANS FOR MANNED SPACE STATIONS IN EARTH ORBIT

The United States cancelled Apollo lunar landing missions after Apollo 17 and made available for space station work a Saturn V launch vehicle from the remaining small stockpile, after production of these launch vehicles had ceased. Its experimental space station was called Skylab, and was launched on a Saturn V in 1973. The station was built in the shell of an S-IVB rocket stage, and was accompanied by an associated docking adapter, air lock, and telescope mount. It decayed from orbit in 1979, with some debris recovered in Australia.

Plans for a military Manned Orbiting Laboratory (MOL) were abandoned in 1969 because of budget squeeze and changing technology. Despite the similarity of name, this alternate program was to operate in so different a mode that it was never competitive with Skylab; the only common factor was that it was manned.

In September 1969, a special task group reporting to the President recommended a four-element program for the 1970's which included the already described space shuttle, a versatile space tug for extensive maneuvering in orbit or landing on the Moon, a nuclear-powered rocket ferry for transfers between Earth orbit and lunar or planetary orbits, and a building block system of modules to construct permanent space stations in Earth orbit, and elsewhere. The program was carefully considered technologically, but it involved fiscal peaking problems which were given small chance of winning general national support. Hence, construction of the shuttle is the only one of the four elements recommended by the Nixon Administration for active development (aside from solid-fuel upper stages) that has gone forward.

Part of the gap in the U.S. program will be filled by the Europeans who have built a manned sortie module (Spacelab) to be carried in the shuttle. But because it is not detached from its shuttle ferry, it is not a real substitute for any proposed station module.

Several studies of possible U.S. space station configurations are underway. One concept, sponsored by NASA's Marshall Space Flight Center, would begin as an unmanned platform for science and applications purposes, possibly evolving later into a manned platform using Spacelab modules docked together with a central power unit. NASA's Johnson Space Center has proposed a different concept called a Space Operations Center (SOC) which would be manned and designed primarily to support space operations, such as storing upper stages needed to take payloads from the relatively low orbits accessible by the shuttle into higher orbits. These concepts and others are being studied by NASA, while the Department of Defense is reportedly performing its own studies of the possible utility of a manned space station.

The Soviet Union claimed that its docked combination of Soyuz 4 and 5 in January 1969 represented a rudimentary space station, inasmuch as there were four rooms assembled with four men present. But the ships were docked only a few hours, and the transfer of crews had to be done by EVA, rather than crawling through a connecting tunnel. The ASTP had a slightly better claim to such a label, when five men could visit directly through air locks.

The Salyut space stations from 1971 on can make a real claim to their title, even though the over 25,000 kilogram combined weight (with Soyuz) and 100 cubic meters of interior space fall well short of the 82,235 kilograms

and 357 cubic meters of Skylab. The advantage of Salyut is that it is an on-going and evolving program. The 29 successful flights docking with Salyut 6 have borne this out.

For the future, the Russians speak confidently of building a large and permanent orbital station for many men, for the purpose both of conducting Earth applications work and scientific observation of the stars, and additionally serving as an orbital assembly, checkout, and launch facility to send manned expeditions to the Moon and planets. Keldysh, then President of the Soviet Academy of Sciences, predicted in October 1969 that such a large station might be ten years away but would more likely be available in five years, but by the end of 1981 still had not been launched. It may be that the long awaited large (G) launch vehicle will find use in lifting major components for such a station. At the moment, orbital assembly of small components seems a more likely path.

There is more press and professional discussion world-wide than firm planning for space colonies. A favorite scheme is the L-5 proposal popular in the United States for a 10,000 person colony to be positioned in Earth orbit as far away as the Moon at a Lagrangian point (where the gravitational forces of the Earth and Moon cancel each other out).

C. POSSIBLE CONTINUED SOVIET INTEREST IN MANNED LUNAR LANDINGS

When President Kennedy asked Congress to support Project Apollo in 1961, his advisors had told him this was a project in which the United States had a good chance of being first. They were right, but it would have taken very little different to have come in second.

Many analysts had expected the Russians to be first to make a manned circumlunar flight, possibly to coincide with the fiftieth anniversary of the Soviet state in November 1967. The program slipped, but Soviet unmanned precursors accomplished this mission several times with improving success, although men have not yet been committed. Instead, Apollo 8 was first to carry men to the Moon, and additionally it lingered in lunar orbit, something beyond the capability of the Soviet Zond 4 through 8 flights.

In the early 1960's Khrushchev made seemingly contradictory statements as to whether the Soviet Union was working actively on a lunar landing program, but in net balance his statements and those of other Soviet officials seemed to indicate they were. Until a few months before the Apollo 8 flight, Soviet cosmonauts were saying that when the Americans landed, they would find the Russians there to greet them. This talk ceased until new predictions were made in 1969. In April and June, respectively, Shatalov and Leonov, both senior cosmonauts, predicted that a Soviet manned landing and return would be accomplished some time between October 1969 and the early part of 1970, preceded by some unmanned tests of the entire system. This would seem to indicate that Soviet space officials thought whatever engineering difficulties had held up the unveiling of their very large (G) vehicle had finally been solved.

In actual fact, the absence of appropriate Soviet flights during the summer and fall of 1969 probably indicated that whatever hopes were present in the spring had not been fulfilled. In the October statement by Keldysh, referred to above, he suggested that immediate plans for manned lunar flights

had been set aside, but not precluded for the future. This admission in itself seemed to give substance to there having been such plans earlier. Further, the statement had the advantage of taking the public pressure off their program in the face of delays. But it must be added, it is not clear from what is known of the Soviet program that they had the means to conduct at so early a time a manned lunar landing. Not only would the expected big G vehicle have to be operational, but it would require either high energy upper stages, or have to be used in some pattern of rendezvous operations. The lack of evidence of readiness to go either of these paths as early as 1969 surrounds the cosmonaut predictions with questions. There is circumstantial evidence that subcomponents for manned lunar flights beyond the Zond circumlunar program were flight tested by Kosmos 159 (1967), Kosmos 379 and 382 (1970) and Kosmos 398 and 434 (1971). Some of these might have been used for future lunar orbit rendezvous options as their changes of velocity matched requirements for entering lunar orbit and for descending to the surface of the Moon, and returning to Earth.

Continued slippages in those parts of the Soviet program potentially related to a manned lunar landing suggested that the first flights could not come probably much before the 1980's. If such flights come before the establishment of an orbital launch facility in conjunction with a permanent Soviet space station, they would in most likelihood parallel the kind of interim approach used in Apollo, although possibly differing in detail. In December 1974, the Russians asked India for permission to base tracking and recovery ships in that country, strongly, suggesting a continued interest in lunar recovery

missions with a g-load low enough to carry men as in the cases of the Zond flights. However, no new flights have occurred since then to support any development. Statements in 1978 and 1979 have suggested a preferred mission would be a manned lunar orbital station with only occasional sorties to the lunar surface.

In summary, a Soviet manned lunar landing does not seem imminent, but is still expected as a part of Soviet long range plans. Going to the Moon with men has been talked about so long and prepared for at such expense by the Russians that one must assume they will proceed as soon as they solve their present problems of unreliability of hardware. Our first clues may come from appropriate precursor flights, particularly of the big G vehicle, but also possibly in use of high energy upper stages, and further tests of multiple-burn maneuvering stages.

D. COMPETITION IN SPACE APPLICATIONS

It is within the expected capacity of the United States to improve the completeness and quality of its weather reporting, with some good prospect for providing accurate forecasts of a week or so.

The Soviet Union will probably improve the reliability of its weather satellite equipment, and they are also interested in providing better forecasts. Their theory of weather systems may keep pace with ours, but they may lag for a time in computer capacity on the ground to support weather analysis.

The United States is working with INTELSAT, the international consortium, to provide a growing number of channels to all parts of the world for telephone, television, and computer links. Direct broadcast has come more slowly for reasons of political concern and limited channel capacity, but now is close. Domestic distribution of communications by satellite finally appeared in 1974, but had been delayed by the dispute over control of such systems. Now it shows explosive growth.

The Soviet Union has tried to interest other countries in a Soviet communications satellite system called INTERSPUTNIK, but this has had such a poor reception that the plan has advanced slowly. About five years late, Soviet television service to Cuba has opened. In late 1975 INTERSPUTNIK received a new lease on life with the plan to launch up to eleven large Statsionar satellites in 24-hour synchronous orbit between 1975 and 1980, with five of these longitudinal spots now filled by Ekran, Raduga, and Gorizont payloads. Still more ambitious Soviet plans have subsequently been announced, for 19 more satellite locations registered with the International Telecommunications Union.

The Earth resources field is one which suggests a large expansion of space activity in the next decade. The United States seems likely to go ahead with operational systems, and it would be hard to believe the Russians would neglect further Earth resources work, although their comprehensive plans are not known. In 1979 alone they identified 13 Earth resources missions flown, with eight more in 1980, and seven in 1981.

F. PROSPECTS FOR MANNED FLIGHTS TO THE PLANETS

For a number of years, NASA has studied various kinds of manned planetary expeditions, principally to Mars. Briefly, there was interest in the early 1960s in a fly-by of Mars and possibly of Venus by the late 1970's, using modified Apollo and Saturn V equipment, but this was not seriously entertained in any formal program. When the President's Space Task Group in the summer of 1969 submitted its long range U.S. space plan, it opened the possibility of a Mars landing by men in the 1980's.

The general reaction in the Congress with few exceptions was either indifference or active hostility, and NASA has not pressed this possibility in its official plans.

As mentioned earlier in this paper, a national capability to use space in the late 1970's and thereafter was to be built around use of four types of largely reusable and multipurpose vehicles. The shuttle, already discussed, was the first and most vital. It is important to recognize that the shuttle was not intended to be an end in itself, but represented a design approach to cutting costs and adding capacity for all kinds of missions, whether unmanned, or manned, and whether in Earth orbit or beyond. The second element, already discussed, was the manned station module. This was expected to justify its costs of development and use in practical applications in Earth orbit once such a reliable unit was available, and the shuttle permitted non-astronauts and less expensive payloads to fly to and from orbit safely at more moderate cost. Purely as a dividend, such a unit could also have

been used at nominal additional cost in orbit around the Moon, on the surface of the Moon, or for flight to the planets.

A third element was a space tug, to have been used in assembling components in the vicinity of the future permanent space station, shifting payloads to synchronous orbit, or landing major components on the Moon as successor to the transport capabilities of the Apollo lunar module.

Only the fourth element of the proposed national program was aimed primarily at deep space work: the nuclear-powered orbital transfer shuttle, also reusable, both for major movements to and from the Moon or in planetary flight. (All U.S. nuclear propulsion development was halted in the early 1970's.)

When some Members of Congress reacted very negatively to the report of the Space Task Group, the very existence of the shuttle, which was intended to be so important to cutting costs near Earth, was threatened by the charge that it represented a back-door attempt to gain a manned planetary program without explicit approval. Consequently, little has been said about planetary flight since then by NASA in connection with the shuttle or other program elements.

When the United States decided to send men to the Moon, it had to construct an entirely new capability whose cost totaled $21.35 billion up through the first landing. Successive flights were priced at $450 million or so, once the initial investment had been made. It was not surprising, in discussing the much greater challenge of manned planetary flight, that it soon became common in political circles to put a $100 billion price tag on a first expedition to Mars. Considering that equipment would have to work reliably for about

two years instead of two weeks, the needed redundancy for safety as well as the initial logistics requirements would add up to a fairly ambitious undertaking if the Saturn V and Apollo technology of 1961 were to be used. Human health reactions on such a long flight have also been questioned, despite some partial long-duration tests of closed cabins on Earth, as well as use of the Skylab flights.

The motivation for the Space Task Force plan was by no means exclusively for creating a capability to fly to Mars; but perhaps the number of words devoted to the subject in the report, related in part to sounding out public support for an inspiring new goal, was misplaced in the climate of apathy and even hostility which followed so quickly after the Apollo 11 success.

The marginal cost per kilogram of payload by using the shuttle to attain Earth orbit was originally expected to drop from $1,500 to about $330 in the first generation of this class. This cost advantage has largely eroded away, but there is still hope of at least breaking even with expendable vehicles on launch costs. However, the shuttle also affords major opportunities to cut the cost of payloads through changing the flight environment, removing the extreme cost sensitivity to launch weight, and permitting recovery and repair of expensive payloads.

The shuttle justification was built almost entirely around these economic data for Earth applications. Yet it is true that the potential will be created for more distant flights as well. For example, the estimate is that Apollo/Saturn V hardware had an operating cost for round trips to the Moon of $80,000 per kilogram. With the four new elements of the Space Task

Group plan, this operating cost would have fallen to about $800 per kilogram, or only one percent as much. (All figures have to be adjusted for inflation.) In similar fashion, planetary flights fall drastically in cost, and even allowing for all the special payloads that might be required, a Mars expedition in the late 1980's might be priced at a figure far closer to $10 billion (1971 dollars) than to the former estimate of $100 billion (1971 dollars). This is not a question which must be decided now, but as elements of the four types of reusable vehicles may be added to the national capability, each justified on other grounds, we may find that we have kept our options open for this later period in our history. The unmanned planetary explorers may bring back the data which will answer whether there is a reason to send men as well.

As already indicated, the Soviet Union has talked more positively about manned flight to the planets (even as recently as 1981), and it is hard to doubt their ultimate intentions in this regard as one studies their total program effort. But to carry out such flights will face them with the same technical and financial questions which the United States will have.

This brief review does not assess the ultimate consequences of pursuit of such goals or failure to undertake them. Some people are already convinced that no set of circumstances would warrant the effort. Others are hardly deterred by the difficulties, expense, or uncertain results. It is hard to accept philosophically that mankind would forever exclude the possibility of visiting most parts of the Solar System. The late President Eisenhower saw practical reasons for limiting space expenditures, but even his first public report on space goals accepted in principle flights by men to Mars, as have most other U.S. Presidents since that time.

F. COOPERATION BETWEEN THE UNITED STATES AND SOVIET UNION

While the principal feature of the relationship between the United States and Soviet Union has been competition, the two countries have also cooperated throughout the years as well. The most long-standing and successful cooperative arrangements have involved the exchange of scientific data from planetary programs, and of space biology information. The Soviets have launched three biosatellite missions (in 1975, 1977 and 1979 respectively) which have carried U.S. experiments, and a fourth such mission is planned for 1982. Five major treaties concerning space activities have been negotiated at the United Nations.

Two principal motives for cooperation offered have been to lessen tensions politically, and to save money. The question of tensions may be more influenced by broader political issues than technical cooperation. Money savings are problematical, except as someday sharing of data might permit a division of missions as between one planet and another, for example. Useful also are the proposed biomedical data exchanges.

The question in the 1960's of whether the Russians and Americans could go to the Moon together was asked more in a rhetorical sense than as a concrete offer by either side. Each side probably was somewhat reluctant to pursue such a goal too openly during any period that one or the other was markedly ahead. Nor has either been willing to give up any basic, independent capability to operate in space, which might be implied by such a division of labor as specialization in launch vehicles or spacecraft.

The most ambitious joint program was the Apollo-Soyuz Test Project (ASTP) already described. ASTP came off technically without a serious hitch,

but was quite controversial. Challenges were made on the grounds of cost, safety, technology transfer, and Soviet image-building. Because the program was largely dead-ended technically, and the amount of science was slight in relation to the investment, the cost was criticized. Unknown problems of systems compatibility and worries about Soviet equipment unreliability led to some political demands that the program be suspended for much more detailed studies. There were worries that the United States was giving away more technology than it was gaining. A Soviet program which had faltered was presented to the world as an equal partner through ASTP. The Soviet investment in test flights and back-up hardware was probably at least as great as the U.S. investment in the docking module which it supplied. Most of the safety charges lodged against the Russians were based upon launcher problems such as their April 5, 1975 aborted Soyuz, not wholly applicable to the space orbital meeting. Both sides were rather careful not to give away really private technology. The Russians surely gained first hand insights into NASA management methods and documentation, and the Americans visited Soviet facilities and people never before available. It is not clear that the Soviet program needed a political boost in image considering its massive size and many successes.

The future of U.S./Soviet cooperation has been clouded by international tensions. After the imposition of martial law in Poland in late 1981, President Reagan announced sanctions against the Soviet Union for the role it is believed to have played in that situation. Among the actions taken by Reagan was the announcement that the United States would not renew scientific agreements with the Soviet Union, including the space cooperation

agreement which expires in May 1982. The status of projects like the 1982 biosatellite mission which were begun while the agreement was in force, but will not take place until after it has expired, is unclear. The State Department is expected to decide on what to do about the biosatellite project in early 1982.

G. SPACE OPTIONS FOR THE 1980s

The overall space policy of the United States is embodied in the 1958 National Aeronautics and Space Act. Through the 1960's, the country focussed its efforts on meeting the 1961 goal established by President Kennedy to land men on the Moon by the end of the decade. As discussed previously, a panel was established near the end of the 1960's to establish goals for the U.S. space program following completion of the Apollo program, but only the space shuttle remains of those ambitious proposals.

During the 1970's, the executive branch proposed no major space mission initiatives of the order of magnitude of the Apollo program. In 1978, President Carter issued two space policy directives in an attempt to give guidance to the U.S. space effort, but they were subsequently criticized for not proposing specific programs. Congress responded with the introduction of several bills to specify programs which could be accomplished in the next ten to thirty years, but none was reported from committee. President Reagan initiated a space policy review of his own during his first year in office, and the results are expected in mid-1982.

As already described, the space shuttle has absorbed a very large portion of the available funds, and the policies of making do with limited funds have stretched the program extra years and run up total costs. There have been arguments over how many space shuttle orbiters should be built, and whether there will be payloads to fill them. Currently, all flight space is booked on available shuttles through 1987, with some payloads having to be diverted to expendable rockets, both American and European, to meet critical user deadlines.

In the applications area, a principal development has been to remove the limits on numbers of communications satellites, so that now a shortage of "parking" spaces along the Equator is a matter of domestic and international contention. Another principal development has been to find a way of moving to an operational Earth resources satellite system, with many different options for ownership, management, and systems design.

The proposal to meet energy shortages caused by limits to available fossil fuels by building solar power satellites attracted some interest from 1977-1981. Large collectors of sunlight in high orbit would convert solar energy to microwave or laser form for transmission to Earth where it would be transformed into electric power. Industrial groups pushed energetically for demonstration projects, if not full scale development, while environmentalists raised many questions about side effects, and other analysts have questioned the cost/benefit potentials as compared with greater exploitation of less-utilized fossil fuel sources, bio-mass sources, nuclear energy, and ground-based primary solar collectors. Government studies completed in 1980

and 1981 explored these issues, but did not resolve them. No funding has been provided for development of this concept since 1981.

In the area of space science, a backlog of projects suggested by advisory panels remains unfunded. A Space Telescope to be carried in the shuttle will be launched in 1985, and plans are underway for a Gamma Ray Observatory to be launched in 1988. After the spectacular achievements of the Viking missions to Mars, Pioneer missions to Venus, and Voyager missions to Jupiter and Saturn, a gap of at least five years has developed in future planetary exploration. The VOIR mission for the further mapping and exploration of Venus has been cancelled, and Galileo, the Jupiter orbiter and probe mission is the only surviving U.S. planetary mission in development. The United States decided not to take advantage of the once-in-almost-a-century opportunity to probe Halley's Comet; it will be explored by the European Space Agency, the Soviet Union, and Japan, without direct U.S. participation.

The Administration and the Congress will not lack for difficult and perplexing choices related to space missions, and to the level of activity which is appropriate. The decisions will be made more difficult by lack of agreed upon facts as to the current, intermediate, and long term payoffs in economic benefits, national defense, and understanding of nature, on which, presumably, human well-being may depend as energy needs become harder to meet, and the environment is further threatened by man's activities.

With the increasing involvement of the Department of Defense (DOD) in space activities, and the continuing constraints upon NASA's budget for civil space programs, one question that is receiving increased attention is whether the two programs should continue as separate entities. President

Eisenhower separated the military and civil space activities because he wanted to show the world that the United States was intent on using space for peaceful purposes, while recognizing that they were useful military space activities as well.

In 1981, the budget request for FY82 space expenditures of DOD surpassed NASA's space budget request for the first time. In fact, the DOD space budget would be even larger if NASA-funded development of the space shuttle was taken into account (DOD is expected to require two of the four authorized space shuttle orbiters for its operations). Since NASA is a research and development agency, it is not expected to be the operator of the shuttle system once it is completely developed, and one possibility is that DOD will operate it for all users--civil, military, and commercial. (Another possibility is that DOD would operate it only for government missions, while a private sector group would be in charge of commercial and foreign users.)

If no major civil space intiative is identified for NASA in the 1980's, the agency would have little to do other than space science programs, since the Reagan Administration is proposing to transfer most space applications and aeronautics programs to the private sector. Under these circumstances, there is concern that the Administration will recommend that NASA be abolished, with the space science activities taken over by another agency such as the National Science Foundation. The future of this issue is at least partially dependent upon the results of the space policy review now underway in the executive branch.

In contrast to the U.S. situation, the 1980's could be a period of substantial achievement by the Soviet Union including permanent occupancy of expanding manned orbital facilities with a capacity to support industrial and resource applications. It would not be unexpected if the Soviets launch a reusable spacecraft during the 1980s. It would be difficult to conclude these achievements will not have impacts on U.S. policy toward space.

PART II

SPACE ACTIVITIES OF CHINA, EUROPEAN SPACE AGENCY, INDIA AND JAPAN

Past editions of this report have included text only on the space activities of the United States and Soviet Union, although launch activities of other nations have been noted in the various tables. The 1980's are likely to witness the emergence of at least four additional launching countries/organizations, so these have now been added: China, the European Space Agency (a group of eleven European nations), India, and Japan.

Four other countries--Australia, France, Italy, and the United Kingdom--are sometimes also referred as launcher countries, Australia and Italy because of the launch facilities they have operated, and France and the United Kingdom because of the launch vehicles they developed in the past. Neither the French Diamant or the British Black Arrow are in use any more, however, so they are not included in this discussion. The Australian launch facilities at Woomera are no longer in operation, and although the Italian-operated San Marco platform off the coast of Kenya is used occassionally, it does not involve use of Italian launch vehicles, so Italy is not included either.

A number of countries other than the United States and Soviet Union have significant national space programs, including France and Germany which also participaate in space activities as members of the European Space Agency. This report does not include these national programs because of space and time considerations, but an extensive treatment of the space activities of all countries in the world except the United States and the Soviet Union can be

found in the report World-Wide Space Activities, prepared by the Science Policy Research Division of the Congressional Research Service for the House Committee on Science and Technology. Since that report covers the years through 1977, the following overview of the Chinese, ESA, Indian and Japanese space programs will discuss only the period since then. This overview is not intended to be an exhaustive treatment of the space activities of this countries, but only to provide general information and trends. Tables 1, 3, and 4 provide statistics on annual launches made by these countries.

CHAPTER ONE: CHINA

Since 1977, China has made two successful space launches: China 8 in 1978, and China 9 in 1981 which carried three space physics payloads (one reportedly was a ballon tethered to a solid sphere). This latter launch was an important step in the evolution of the Chinese space program, and may have utilized a new launch vehicle. The Chinese have not identified the launch vehicle which was actually used, but some western experts speculate that it might have been the Long March 3 rocket. If this is true, the Chinese have become the third entity (after the United States and the European Space Agency) to launch a vehicle using high energy liquid fuels (liquid hydrogen/liquid oxygen). The Long March 3 has been in development for some time, and according to the Chinese is very similar to ESA's Ariane launch vehicle, although slightly less powerful. It reportedly can (or will be able to) launch 800-900 kilogram payloads into geostationary orbit.

During 1979 and 1980, the Chinese expressed great plans for utilization of space, and even had astronauts in training for a time. In late 1980 and early 1981, however, the Chinese pulled back from their expansive plans because of a reassessment of the Chinese economic situation. Agreements to purchase broadcasting satellites from the United States were cancelled, and the Chinese announced that its manned space program had also been dropped at least for the remainder of the decade. Since that time, they have indicated that rather than buying broadcast satellites from abroad, they will develop their own, for launch possibly as early as 1983 of 1984.

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The Chinese are apparently continuing with plans to purchase a Landsat receiving station from the United States, however, which may also be able to receive data from the planned French SPOT earth resources satellite, planned for launch in 1984.

The Chinese launch vehicles, like those of the United States and Soviet Union, have been developed from military rockets. The advent of the Long March 3 launch vehicle would also indicate that the Chinese have a significant ICBM capability. It is thought that the ICBM version of this vehicle was tested during 1980. Several of the Chinese satellites launched to date are thought to be related to the development of military reconnaissance satellites.

CHAPTER TWO: EUROPEAN SPACE AGENCY

The European Space Agency (ESA) is a group of eleven European nations (with two associate members). Since 1977, a major ESA activity has been development of an independent launch capability. In 1981, ESA successfully completed the third and fourth test flights of the Ariane launch vehicle, and declared the system operational. (The first test launch in 1979 was also successful, although the second test, in 1980, failed.) France played the lead role in developing Ariane.

Ariane may have important ramifications for U.S. space policy because it will compete directly for commercial traffic with the space shuttle. Ariane can lift 1,780 kilograms into geostationary orbit, or two conventionally sized satellites, thereby reducing costs to the users. The Europeans also offer attractive financing plans where the user makes a relatively small down payment, and then does not have to pay the balance until six months after launch, when the satellite is producing revenue for the user. By contrast, users must pay all costs in advance for launches via U.S. boosters, whether the expendable type such as Delta or Atlas-Centaur, or by the space shuttle. Another advantage of Ariane is that its launching schedule can be planned with greater certainty than the shuttle, since the latter is still in the test stage. As a result, Ariane is looking increasingly attractive to commercial satellite users, and in 1981, three U.S. companies which had planned to use the shuttle switched to Ariane instead (GTE, Southern Pacific, and Western Union). Ariane is marketed by a private organization called Arianespace based in France.

Ariane was used to place two ESA satellites in orbit during 1981 (METEOSAT for meteorology and MARECS for maritime communications), and one Indian satellite (APPLE for communications). The first operational flight of Ariane is planned for April 1982. ESA has approved plans to proceed with further development of the Ariane design. Included in ESA's plans is a version of Ariane which could send probes into interplanetary space or to the planets.

ESA's space activities encompass a wide range of science and applications satellites, and its programs have involved a considerable degree of cooperation with the United States. This cooperation has resulted in some discord, however, because of budget constraints within NASA which led to cancellation of the U.S. half of a joint project called the International Solar Polar Mission (ISPM). Originally, ISPM would have involved the launch of two probes to simultaneously study the north and south poles of the Sun. ESA and NASA would each have provided one spacecraft, and NASA would have supplied the power unit (a radioisotope thermal generator), launch, and tracking for both probes. In 1981, the United States unilaterally abrogated the memorandum of understanding with ESA on ISPM, prompting formal statements of displeasure from several ESA member countries to the U.S. State Department. Nevertheless, the mission could not be accommodated within NASA's budget, and the U.S. spacecraft was cancelled. NASA has promised to keep its commitment to provide the power unit, launch, and tracking for the ESA spacecraft, however.

Relations between NASA and ESA have cooled slightly because of the ISPM incident, but it seems likely that the two agencies will continue to develop certain programs jointly. For example, ESA is reportedly discussing the possibility of using some of its Spacelab modules to construct an orbiting space station in cooperation with NASA. Spacelab, another major cooperative venture between ESA and NASA, is a scientific laboratory which can be carried inside the cargo bay of the space shuttle, thereby providing a "shirt-sleeve" environment for performing a wide variety of experiments. Spacelab pallets have also been developed by ESA for use outside the habitable module for those experiments which require exposure to the space environment. The first Spacelab module was turned over to NASA in December 1981, and the first Spacelab flight is now scheduled for September 1983.

ESA is proceeding with follow-on development of Spacelab. In addition to the space station concept mentioned earlier, ESA is also improving Spacelab to provide for durations of up to one month in orbit, and constructing an automatic space platform for Spacelab pallets.

Among ESA's other on-going programs is the Giotto project to send a probe to intercept Halley's comet when it returns to the Earth's vicinity in 1985-1986. A proposal to send a U.S. probe to the comet was dropped because of budget constraints, and ESA later rejected a NASA proposal for a joint ESA/NASA comet mission. The Soviet Union and Japan are also sending probes to Halley's comet and an agreement between the three entities is being negotiated to provide for exchange of data from the missions. ESA also is developing an earth orbiting astronomical observatory called

Hipparchos for launch in 1986, and an x-ray astronomy satellite called EXOSAT for launch probably in 1982. The agency has also recently approved plans for a project called L-Sat, an experimental multi-purpose communications and broadcasting satellite.

ESA is in the process of developing a ten-year plan for its activities. Among the candidate missions is a remote sensing satellite, ERS-1, which would study the oceans and is scheduled for launch in 1984. If this program proceeds, ESA would become one of the increasing number of countries/agencies with its own remote sensing satellite system (the United States and Soviet Union already have such satellites, and India, France, and Japan have plans underway).

CHAPTER THREE: INDIA

India has been involved in developing satellites and launch vehicles for many years. Its first satellite, Aryabhata, was launched by the Soviet Union in 1975. While cooperation with the Soviets has continued (they launched two remote sensing satellites, Bhaskara 1 and 2, for the Indians in 1979 and 1981 respectively), India has also pursued development of an independent launching capability.

The first test launch of the Indian booster SLV-3 failed in August 1979. The Indians achieved success with their second test launch on July 18, 1980, however, which placed the Indian satellite Rohini 1 into earth orbit (it remained in orbit until July 1981, longer than expected). The third SLV-3 flight took place on May 31, 1981, and although it succeeded in placing Rohini 2 into orbit, the altitude was lower than planned and the satellite decayed after only nine days (instead of the expected 300 days). The Rohini satellites are primarily for monitoring the performance of the launch vehicle, although Rohini 2 also carried remote sensing equipment. Some Western sources have suggested that the Indians are attempting to develop a military reconnaissance capability.

The Indians also built a communications satellite, APPLE, which was launched by ESA on the third Ariane test flight in June 1981. One of the solar panels did not deploy properly, but the satellite is operational.

India's space plans for the rest of the 1980's reportedly include several more launches of the SLV 3 and advanced versions of it, including a polar orbiting capability, and eleven more satellites (some of which will

be built by India and others which will be purchased). The Insat-A communications and meteorology satellite is the next Indian satellite scheduled for launch; it is being built for India by the U.S. Ford Aerospace company and will be launched by the United States.

Western press reports have indicated that India plans to spend approximately $400 million on its space activities between 1982 and 1985, and another $500 million between 1985 and 1990. The focus of the Indian space program is development of launch vehicles, communications, remote sensing, and meteorological satellites. India has also accepted an invitation from the Soviet Union to send an Indian cosmonaut into space (the Soviets have already launched representatives from the nine Interkosmos countries, and plan to launch a Frenchman in 1982). This flight is expected around 1983-84.

CHAPTER FOUR: JAPAN

Over the past several years, Japan has released space program plans for the future which involve a very ambitious level of activity for that nation, including the possibility of launching astronauts on the U.S. space shuttle and possibly developing its own manned program. To date, however, the Japanese space program has focused on development of launch vehicles (based on U.S. technology), and communications, weather, and scientific satellites.

Japan uses a mixture of U.S. and Japanese technology in its space activities. More than 20 satellites have been orbited by Japan, some of which were purchased from U.S. aerospace companies, while others were built by Japan. During the early years of the program, most orbital launches were provided by the United States, although at the present time Japan relies on its own launch vehicles. There has been a great deal of cooperation between the two countries and it is expected to continue.

Japan is also likely to offer stiff competition to the United States, although unlike ESA, it is not likely to be in terms of providing launch services. Rather, Japan seems likely to compete in the area of space technology itself, particularly communications satellites.

In 1977, the Japanese launched the first experimental communication satellite to operate at the frequencies of 30/20 Gigahertz. Most communication satellites today operate at lower frequencies, and those bands are becoming congested; 30/20 GHz technology is anticipated to be the wave of the future. In the United States, policy disputes over whether the Government

or private industry should pay for developing advanced communication satellite technology such as this has slowed development of U.S. technology, while the Japanese have forged ahead. They plan to launch their first operational 30/20 GHz satellite, CS 2, in 1983.

Development of communications satellites in Japan did not take place without difficulties, however. In 1979 and 1980, Japan lost two communications satellites (Ayame 1 and 2) after launch. The first satellite impacted the upper stage of its launch vehicle after separation, and the second was lost when the apogee kick motor used to place the satellite in geostationary orbit malfunctioned. In the latter case, the kick motor had been purchased from a U.S. company, and the Japanese subsequently indicated that they would develop their own kick motors for the future.

The Japanese have relied on the N launch vehicle for most of their launches since 1977. The N vehicle is manufactured by the Japanese under license from the United States, using technology developed for the U.S. Delta booster. In 1981, the Japanese successfully launched the first improved version of the N launch vehicle, N II, which can place 350 kilograms in geostationary orbit. They also announced plans to develop an H-1 vehicle which will be able to place 550 kilograms in geostationary orbit, and will use liquid hydrogen/liquid oxygen fuel. The 1969 agreement with the United States which allows access to the Delta technology prohibits Japan from transferring that technology to third countries and from launching satellites for third countries without prior agreement from the United States. Because of this latter provision, Japan is not seen as a near-term launch competitor

to the United States. Another limiting factor is that, for financial reasons, the Japanese can only launch twice a year because the government is required to compensate the Japanese fishing industry on days when launches occur (for safety reasons, the fisherman cannot be in the water near the launch site).

In 1981, Japan launched three satellites: two with N II booster (the ETS 4 engineering test satellite and the GMS 2 meteorological satellite), and one using the Mu vehicle (Astro-Hinotori, a scientific satellite).

For the future, Japan continues to have ambitious space plans. Among the approved programs is a mission to Halley's comet, planned for launch in 1985. Called Planet A, the probe would first return data about Venus and then continue on to intercept Halley's comet. As noted earlier, Japan, ESA and the Soviet Union are developing a cooperative agreement for exchange of data from their individual Halley's comet probes. Other approved programs focus on developing more advanced communications, meteorological, and remote sensing satellites. In the latter category, the ERS satellite is scheduled for launch in 1986 and will help explore for oil and mineral resources. Current plans call for the satellite to carry a synthetic aperture radar, a stereo camera, and visible and infrared radiation measurement systems. Also planned is a Marine Observation Satellite for launch in 1985 to study ocean surface temperatures.

In 1981 the Japanese also raised the possibility of launching military reconnaissance satellites. The 1969 space cooperation agreement with the United States requires Japan to use U.S.-derived space technology only for peaceful purposes, so the United States might have to approve any reconnaissance satellite activities the Japanese plan.

An even more ambitious proposal is for the construction of a "mini-shuttle." Smaller than the U.S. space shuttle, the Japanese version would have most of the shuttle's basic features, including reusability, and could carry a crew of four. This proposal is in the very early stages of discussion and has not been approved.

APPENDIX

Conversion of Metric to English Measures

All data in this report have been quoted in metric rather than English measures. Only a few such measures are required in this study. For the convenience of readers not as familiar with metric measures, the following brief conversion table is supplied, related only to measures used in this report:

1 kilogram equals 2.20462 pounds avoirdupois

1 kilometer equals 0.6214 statute miles

1 cubic meter equals 35.31 cubic feet

1 meter equals 3.28083 linear feet

1 gram equals 0.03527 ounces avoirdupois

1 centimeter equals 0.3937 linear inches